Instruments

THE MAGAZINE OF MEASUREMENT
INSPECTION · TESTING · CONTROL

cluding the
JOURNAL OF THE INSTRUMENT SOCIETY OF AMERICA

d the
JOURNAL OF THE SOUTHERN CALIFORNIA METER ASSOCIATION

n this issue . . .

Instrument Standardization
Process Stability
Electrometer Applications
Electromechanical Servomechanism
Instrument Electronics
Slurry-service Instrumentation
A-c. Induction Flow Meter
Pulsative Flow
94 New Instruments
106 New Bulletins

Vol. 25 No. 4
APRIL • 1952

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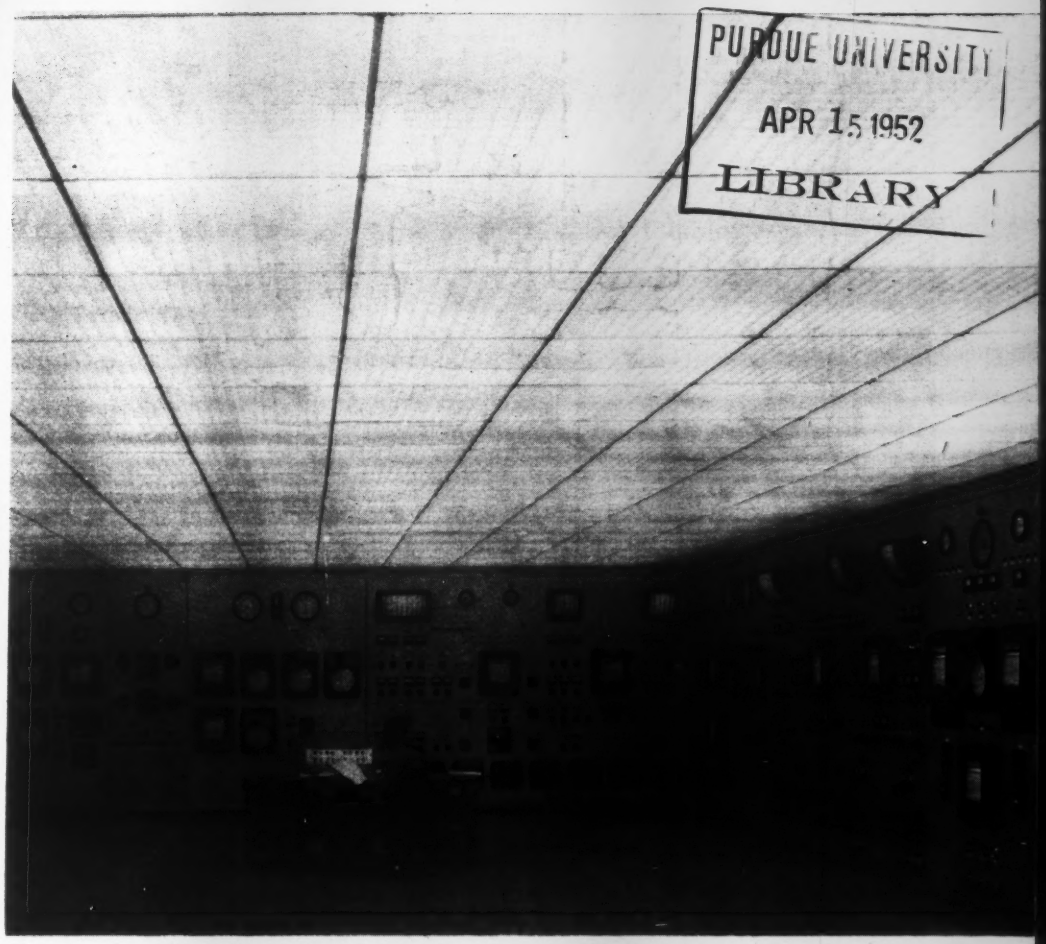
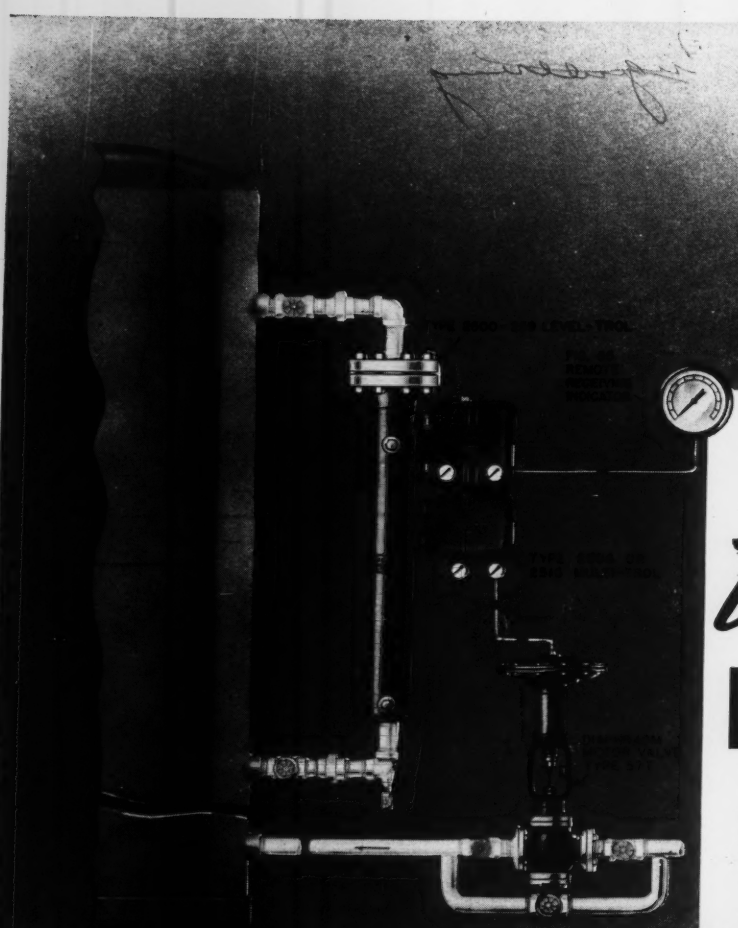


Part of central control room for Pennsylvania Power & Light Company's Sunbury, Pa. station. One man at each end of room can watch all controls for one of the two boiler-turbine units. ***(Photo courtesy Leeds & Northrup Co.)***



New!

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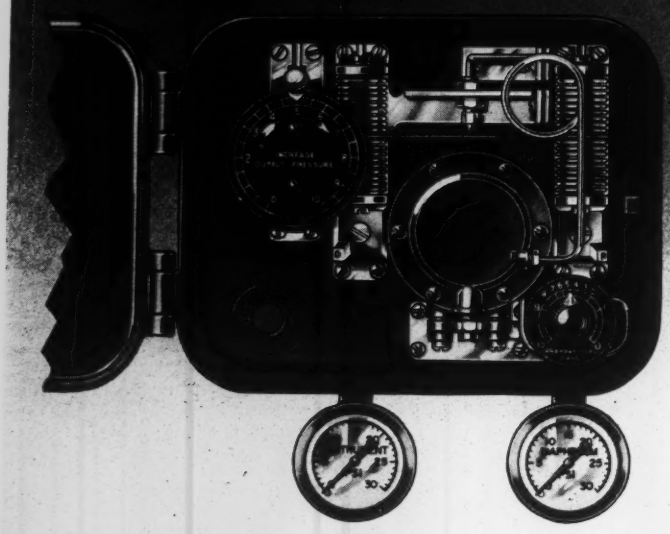
This new Fisher Controller consists of a primary pilot (standard Fisher Series 2500 Level-Trol — used for indicating or controlling level) whose output is transmitted by pneumatic link to secondary pilot — the Multi-Trol.



MULTI-TROL FEATURES

1 — Available with reset (Type 2516) or without reset (Type 2506). (Reset may be added to units originally furnished without it.)

2 — Proportional band adjustment is incorporated into the remote receiver controller with a range of 10% to 200%.

3 — Level control point is adjustable manually in the case by level set adjustment. For remote set — provided with connection for remote air loading.

4 — Pressure balanced type of relay provides intermittent bleed and gives accurate stable control.

5 — Pilot may be changed from a direct acting to a reverse acting unit or vice-versa, thru the use of switch plates.

6 — Pilot may also be changed from proportional action to two position action or vice-versa, by repositioning a switch plate.

Complete information will gladly be sent upon request.

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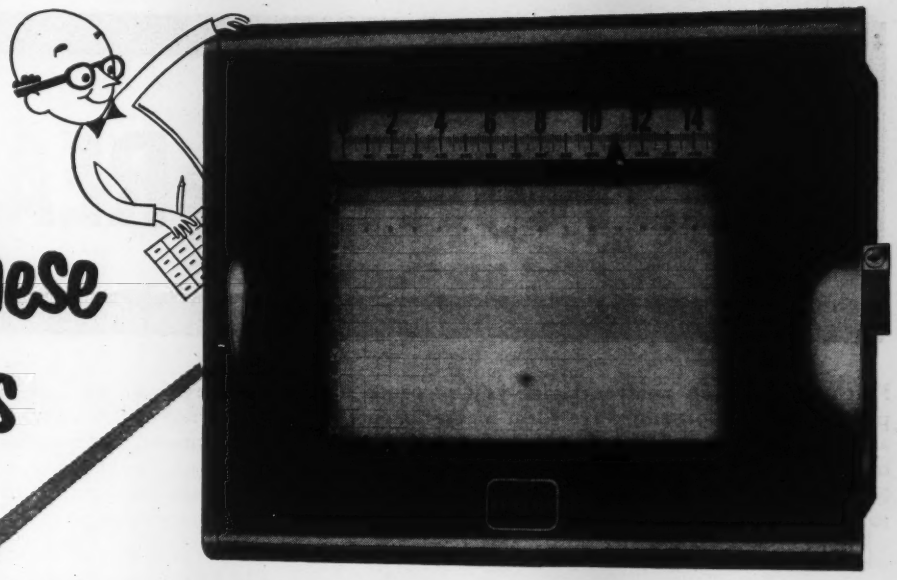

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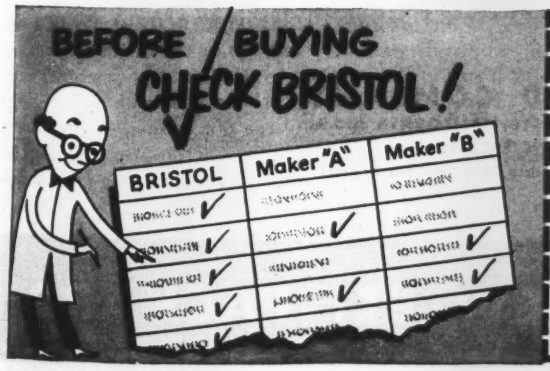

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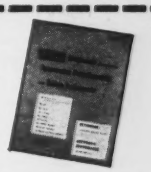

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DISTORTION READINGS.

Fast-operating *-hp-* analyzers give you accurate, dependable distortion and wave form measurements at appreciable savings in engineering time. *-hp-* instruments shown here provide complete coverage between 20 cps and 20 kc; they are basic equipment in laboratories, radio and television stations and on production lines everywhere. Each instrument has the traditional *-hp-* family characteristics of simple operation, minimum adjustment, independence of line voltage or tube changes, generous overload protection and sturdy construction from quality components. For complete information, see your *-hp-* field engineer, or write direct.

For TOTAL DISTORTION MEASUREMENTS

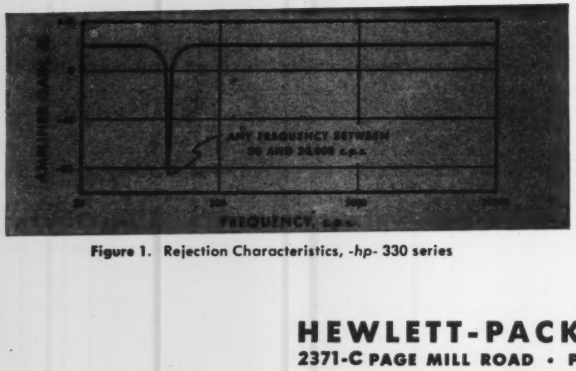

Figure 1. Rejection Characteristics, *-hp-* 330 series

***-hp-* 330B DISTORTION ANALYZER** (left) is an unusually versatile instrument offering fast, accurate measurement of distortion values as low as 0.1% at any frequency between 20 cps and 20 kc. The equipment also quickly determines voltage level and power output, measures amplifier gain and response, measures audio noise and hum (direct readings), determines unknown audio frequencies and serves as a high-gain, wide-band, stabilized amplifier.

This equipment is actually three instruments in one. It includes a high-quality 20 db amplifier with less than 0.1% distortion, a tunable rejection filter offering almost infinite attenuation at any one frequency (see Figure 1), and a wide range, high sensitivity VTVM offering flat response from 10 cps to 100 kc. All of these elements are usable separately, and the amplifier may be cascaded with the VTVM to measure voltages as small as 100 μv.

For BROADCAST MEASUREMENTS

***-hp-* 330C DISTORTION ANALYZER,** for FM measurements, is identical with *-hp-* 330B except that indicating meter movement has VU ballistic characteristics meeting F. C. C. requirements for FM broadcasting.

***-hp-* 330D DISTORTION ANALYZER** is designed for both AM and FM measurements. It includes an AM detector to rectify AM carrier, plus meter movement having VU ballistic characteristics meeting F. C. C. requirements for FM.

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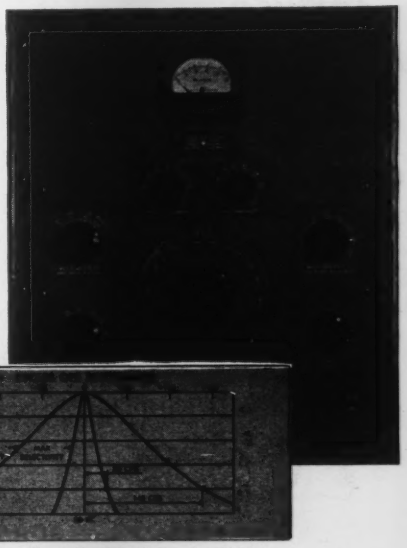
S. . . . 20 cps to 20 kc

For MEASURING INDIVIDUAL WAVE COMPONENTS

-hp- 300A HARMONIC WAVE ANALYZER (right) is a selective voltmeter measuring the value of individual components of complex waves. Its variable selectivity is the key to its speed and versatility of operation. When wave components are close together, a unique selective amplifier can be narrowed to accept only desired components. When components are far apart, selectivity may be broadened to speed measuring without sacrificing accuracy. This feature is also important when measuring waves (such as in sound tracks) where some FM is present. The equipment is also ideal for analysis of noise, broadcast amplifier and network characteristics, recording devices, rotating machinery, hum and for all types of audio distortion measurements.

-hp- 300A is direct reading, covers the audio spectrum from 30 cps to 16,000 cps, and makes possible full-scale readings with inputs of 0.001 to 500 volts. Selectivity may be varied between limits shown in Fig. 2.



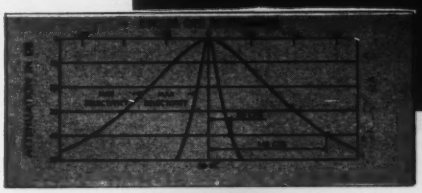


Figure 2. Selectivity, -hp- 300A

For TRANSIENT and FREQUENCY RESPONSE

-hp- 210A SQUARE WAVE GENERATOR provides a convenient, rapid method of determining transient and frequency response in a single measurement. It is widely used for testing receivers, video amplifiers, networks and transmitters; to measure time constants or provide a time base; to check cathode sweep circuits, indicate phase shift, transient effects or frequency response, to generate harmonics or control electronic switchers.

The 210A is an excellent, easy-to-use source of square waves for production line tests and laboratory use. High-quality square waves are generated over frequencies from 20 cps to 10 kc, and the equipment provides usable square waves up to 100 kc.

LOW COST DISTORTION ANALYZERS

-hp- 320A/B DISTORTION ANALYZERS are simple, low-cost devices for determining total harmonic distortion in audio frequency apparatus. They are particularly useful for high-speed production tests. *-hp-* 320A operates at two fixed frequencies: 400 and 5,000 cps. *-hp-* 320B operates at five fixed frequencies: 50, 100, 400, 1,000 and 5,000 cps. Both models require an external detector.

ANALYZER	PRIMARY USES	FREQUENCY RANGE	CHARACTERISTICS	PRICE
-hp- 300A	Wave form analysis.	30 cps to 16 kc	Variable selectivity; measuring range 1 mv to 500 v. 5% accuracy.	$625.00†
-hp- 320A	Measures total harmonic distortion at 2 fixed frequencies.	400 cps and 5 kc	Requires separate detector.	$75.00*
-hp- 320B	Measures total harmonic distortion at 6 fixed frequencies:	50, 100, 400 cps; 1, 5 and 7.5 kc	Same as above.	$150.00*
-hp- 330B	Measures total distortion, frequency tunable.	20 cps to 20 kc	Includes input amplifier and VTVM.	$395.00†
-hp- 330C	Similar to 330B. For FM broadcast measurements.	20 cps to 20 kc	VTVM has special characteristics to meet F.C.C. requirements.	$425.00†
-hp- 330D	Similar to 330B. For AM and FM broadcast measurements.	20 cps to 20 kc	Includes AM detector and special meter to meet F.C.C. requirements.	$440.00†

SQUARE WAVE GENERATOR

-hp- 210A	For rapid determination of transient and frequency response.	20 cps to 10 kc	Output 50 v. peak-to-peak. 1,000 ohm impedance.	$150.00*

*Rack mounting available at $5.00 extra cost.
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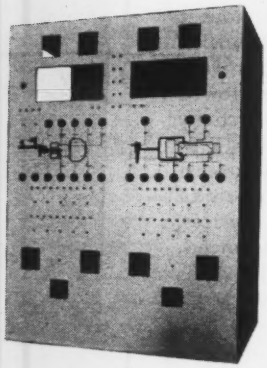

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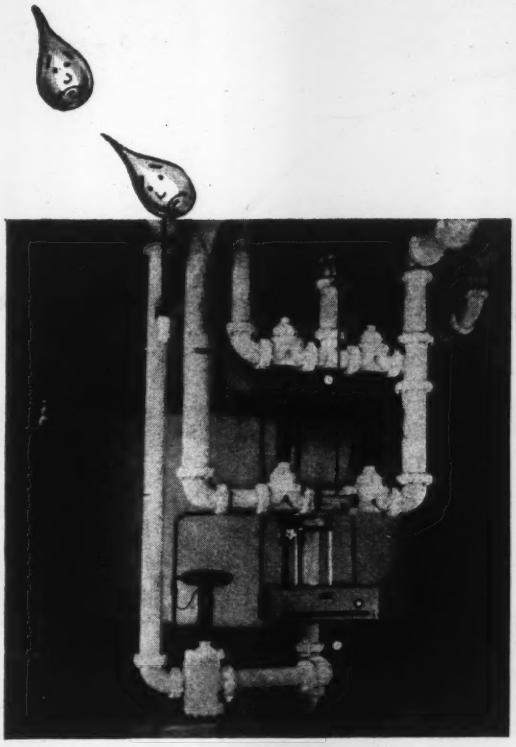

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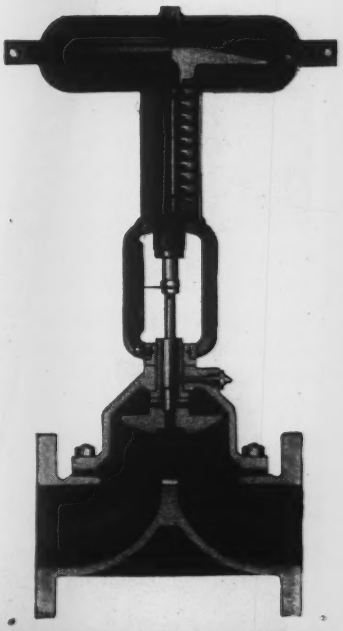

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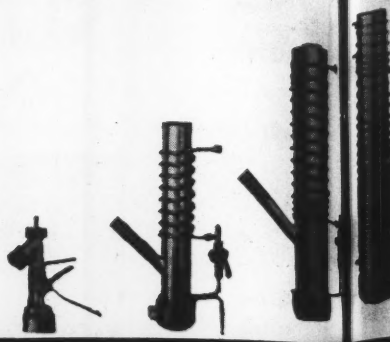

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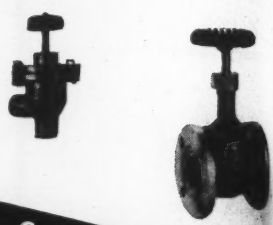

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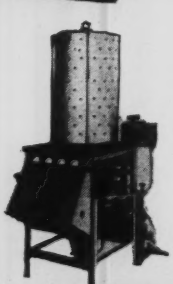

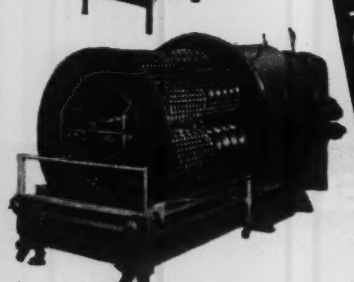

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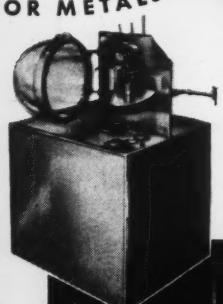

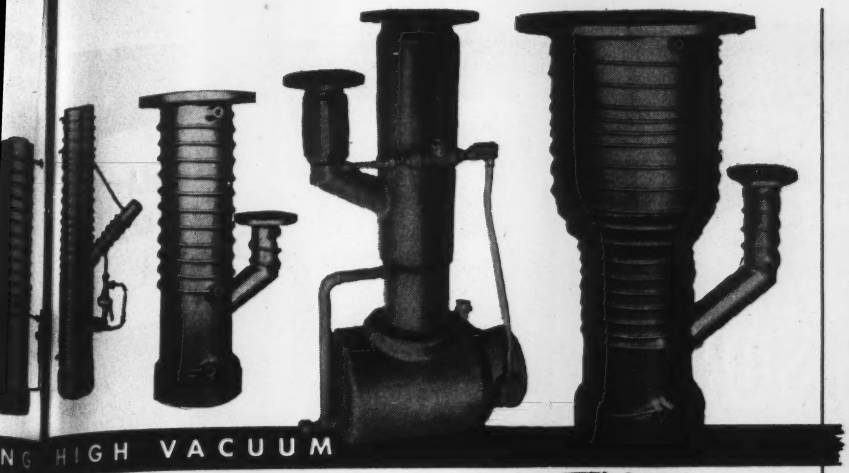

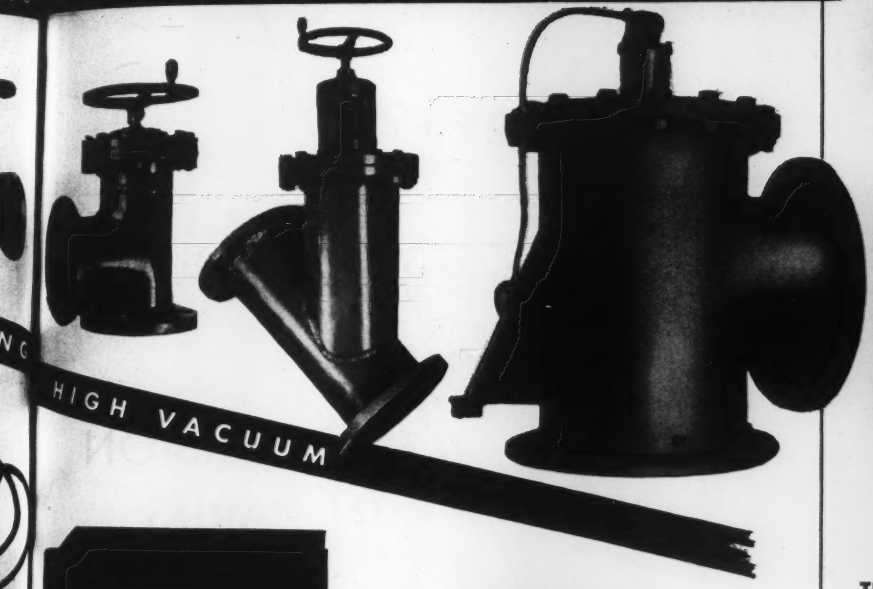

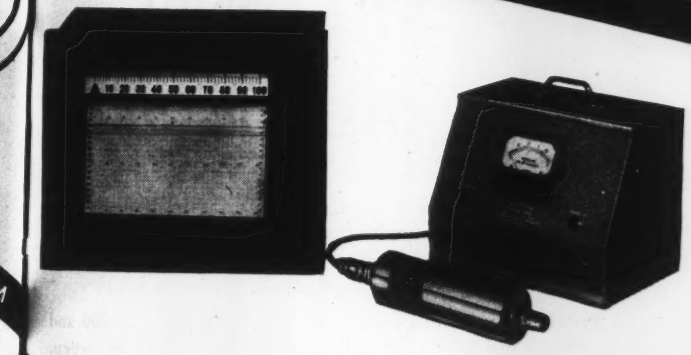

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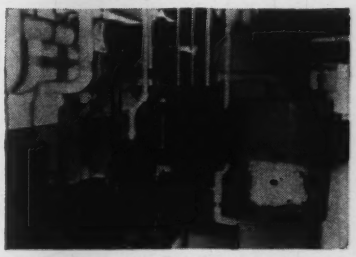

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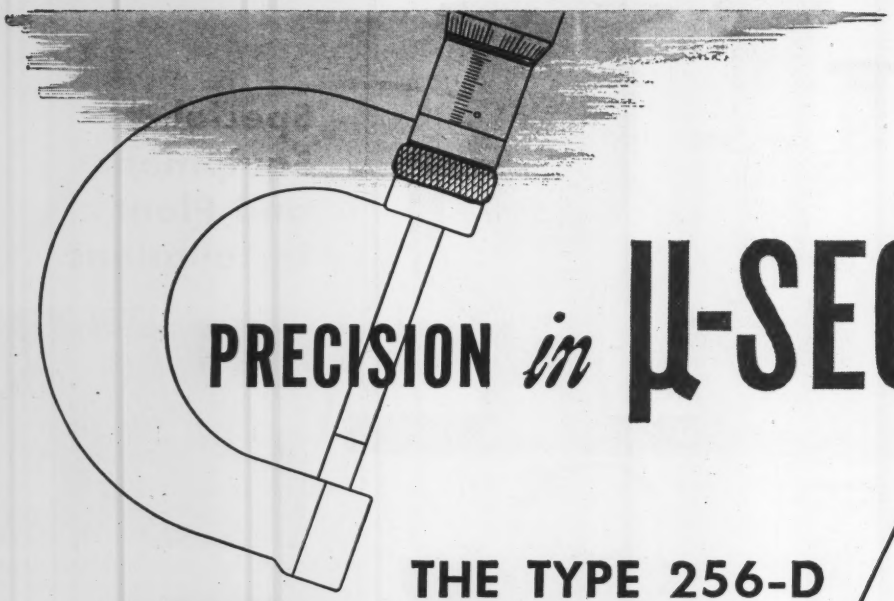

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The calibrated sweep delay of the Type 256-D will measure time intervals up to 1000 microseconds with an accuracy of ±0.1% of the full scale ranges of 100 μ-secs. or 1000 μ-secs. A movable marker indicates the portion of the sweep which is expanded on shorter delayed sweeps. Delayed sweeps are of 4-, 10-, and 25-microsecond durations. Undelayed sweeps are available in six ranges from 4- to 4500-microseconds.

Response of the video amplifier is within ± 1 db at 20 cps; down less than 3 db at 8 mc, no more than 6 db at 11 mc. Sensitivity is 0.7 peak-to-peak volt per inch. Pulse response is such that a rise time of 0.01 microsecond will be reproduced as a rise time of 0.04 microsecond or less.

Crystal-controlled timing markers calibrate the delay circuits. Delayed and undelayed sweeps may be started by external trigger pulses of either polarity or by built-in trigger generator providing 1 microsecond pulses of either polarity, having a rise time of 0.3 microsecond and amplitude greater than 100 volts. Trigger repetition rates up to 2000 P. P. S. are available.

and for PRECISION IN YARDS

THE TYPE 256-E

Electrically similar to the Type 256-D. Calibrations in yards instead of microseconds. Designed especially as test equipment for electronic ranging systems, or as an accessory unit for radar systems.

Provides undelayed sweeps of 800, 2000, 4000, 20,000 and 200,000 yards in addition to a 4500-microsecond sweep. Delayed sweeps of 800, 2000 and 4000 yards may also be selected.

DU MONT

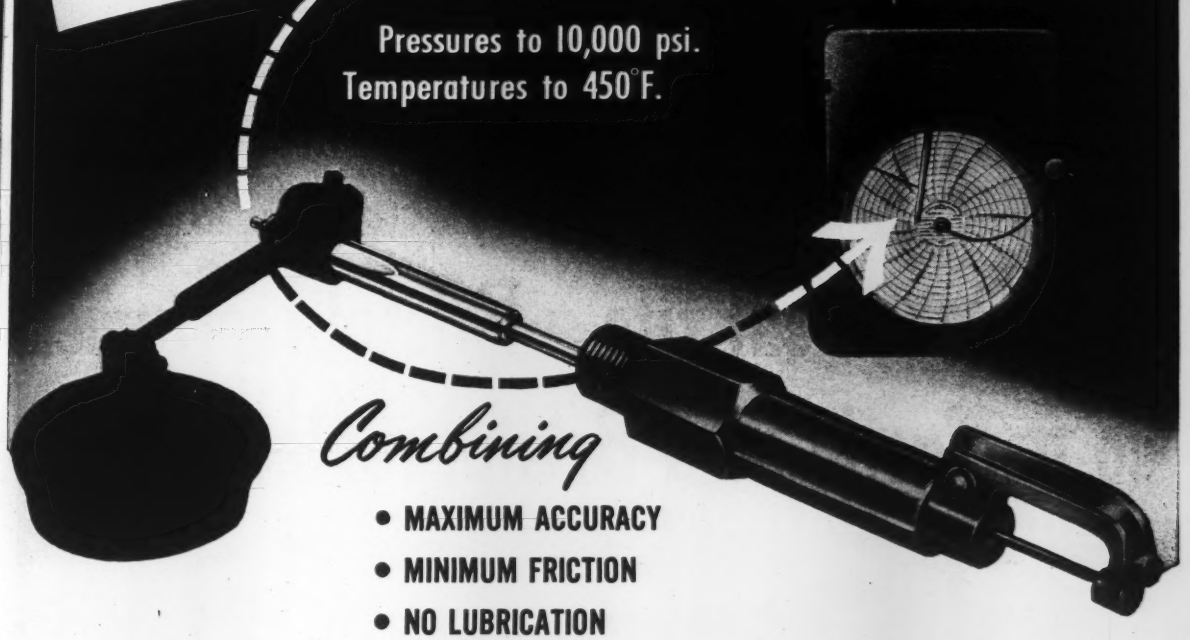
for Oscillography

Instrument Division, ALLEN B. DU MONT LABORATORIES, Inc., 1500 Main Ave., Clifton, N.J.

ANOTHER AMERICAN® ADVANCE

NEW TEFLON SEAL STUFFING BOX FOR HIGH PRESSURE ORIFICE METERS

Pressures to 10,000 psi.
Temperatures to 450°F.



Combining

- MAXIMUM ACCURACY
- MINIMUM FRICTION
- NO LUBRICATION
- NO LEAKAGE
- NO SHAFT FREEZING

New Accuracy! New Efficiency!

This new Type "B" stuffing box extends the benefits of Teflon to heavy-duty high-pressure American Westcott orifice meters — long noted for *simplicity of design, extreme accuracy* and *trouble-free,* dependable service.

The Teflon seal forms a packing and bearing around a precision-made Monel metal shaft of increased diameter for greater rigidity. It is pressure tight, nearly frictionless, *requires no lubrication* and reduces maintenance to a minimum. Other parts are corrosion resistant stainless steel. An external guard protects against shaft damage. The new stuffing box is suited to ambient meter temperatures to 450°F. and pressures to 10,000 psi.

The Teflon bearing and all other stuffing box parts can be removed and replaced in the field. Units are adaptable to older types of American Westcott orifice meters now in service. Write for complete details.

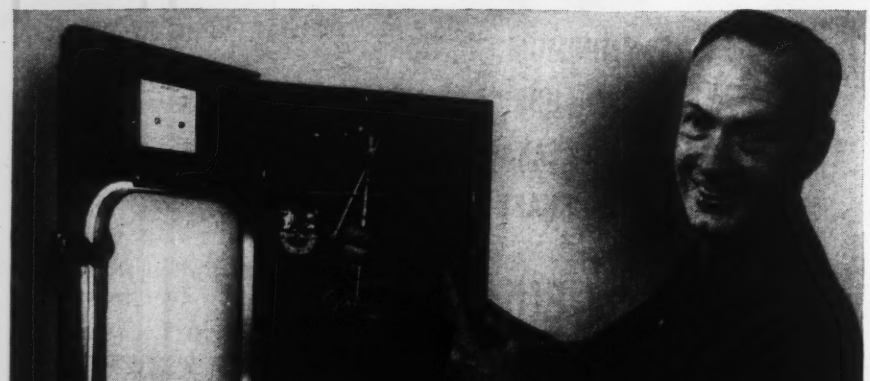
Another example of American's policy of constant product improvement, upholding a century-old tradition of "Sustained Accuracy at Lower Cost."

GENERAL SALES OFFICE: 1513 Race Street, Philadelphia
Albany • Alhambra • Atlanta • Baltimore • Birmingham
Boston • Chicago • Dallas • Denver • Erie • Houston
Kansas City • Los Angeles • Minneapolis • New York • Odessa
Pittsburgh • San Francisco • Tulsa • Canadian Meter Co., Ltd.,
Hamilton, Ontario • Edmonton, Alberta

AMERICAN METER COMPANY EST. 1836 MEASUREMENT ENGINEERS

AMERICAN METER COMPANY

No replacement fits a Bristol Instrument so perfectly as a Bristol replacement*!



*Who is better equipped than the actual maker of the instrument to make component parts that fit it precisely? Don't risk the lack of precision—which even a slight inaccuracy or misalignment in a component may cause—when you can avoid it so easily by simply specifying Bristol replacements. Quick delivery.

THE BRISTOL COMPANY, WATERBURY 20, CONNECTICUT

BRISTOL *The dependable Guidepost of Industry*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

You're sighting on the moose through a Weaver Scope made by W. R. Weaver Company, El Paso, Texas

The Superior Tube That Puts You "On Target"

Hitting specification bull's-eyes to help our customers hit their production targets is a Superior specialty.

A case in point is illustrated above. The customer, W. R. Weaver Company manufactures high-quality telescopic sights for sporting and target rifles. The carbon steel tube in which the lens elements, reticule and eye piece are mounted must be strong and rigid. Tube material must have excellent machining qualities to permit fast, economical, precision working. Because salability depends a good bit on fine appearance, the tube must be extremely smooth and free from pits and scratches. This is particularly true of the larger sizes where tube ends are expanded, making imperfections more evident. Inside surface must also be smooth and to accurate dimensions.

Ordinarily you might expect tubing to fit such requirements for smoothness plus temper and machinability would be a "premium" item carrying extra charges for special handling.

Not at Superior. Here we can take the most exacting specifications in stride because of our experience and "know-how" backed by highly developed production equipment and extensive research and testing facilities.

If you have need for fine, small tubing to do a tough job well, check with us. We can probably fill your requirements from the stocks of our distributors who are located in principal cities. Write Superior Tube Company, 1968 Germantown Ave., Norristown, Pennsylvania.

BE SURE ABOUT TUBING—
SPECIFY **Superior**

THE BIG NAME IN SMALL TUBING

All analyses .010" to 5/8" O.D.
Certain analyses (.035" max. wall) up to 1 3/8" O.D.

ROUND AND SHAPED TUBING

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. UNderhill 0-1331.

Available in:

Carbon Steels:
A.I.S.I.—C-1008, MT-1010, MT-1015, C-1118, MT-1020, C-1025, C-1035, E-1095

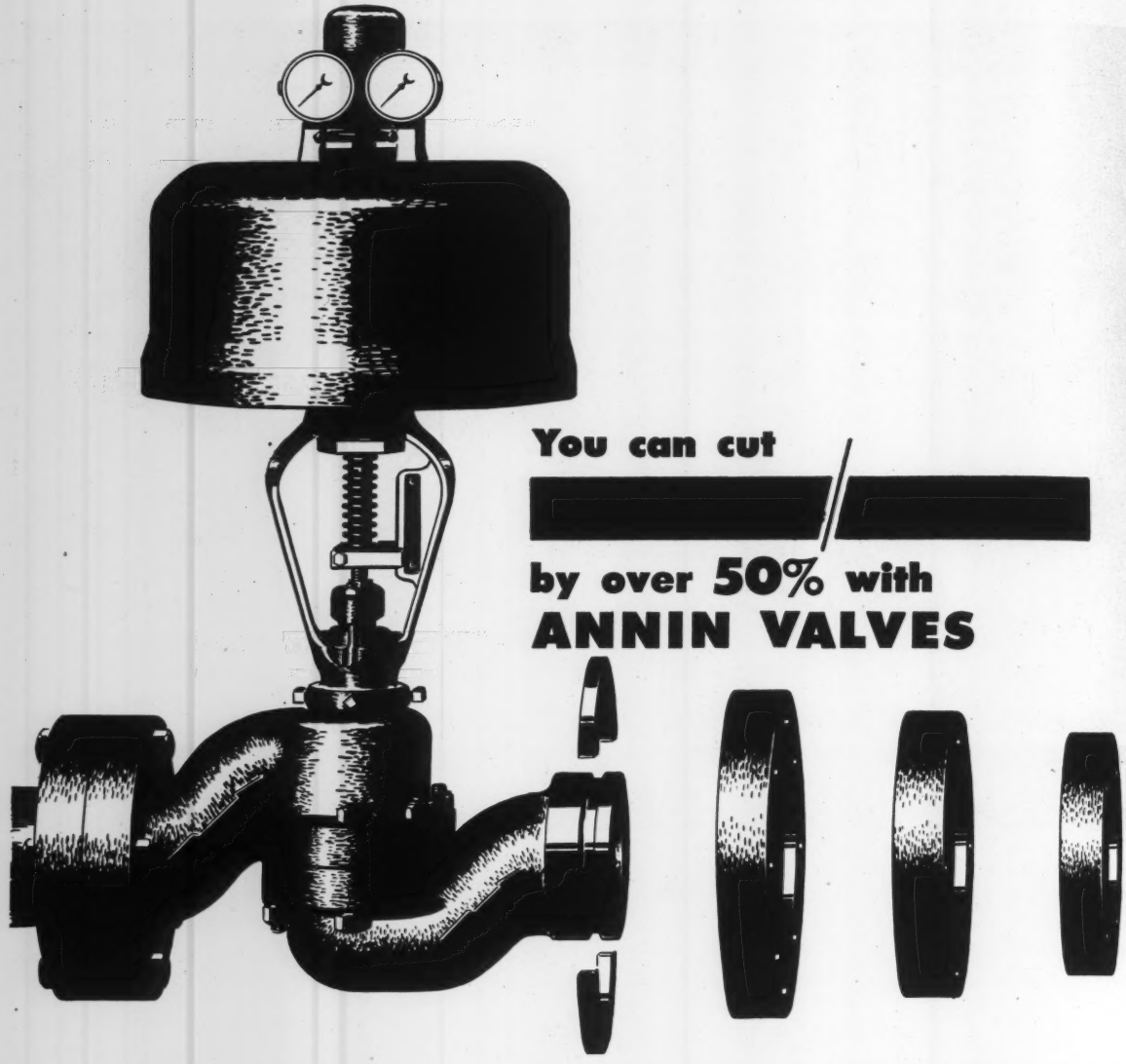
Alloy Steels:
A.I.S.I.—4130, 4132, 4140, 4150, 8630, E-52100

Stainless Steels:
A.I.S.I.—303, 304, 305, 309, 310, 316, 317, 321, 347, 403, 410, 420, 430, 446, T-5

Nickel Alloys:
Nickel, "D Nickel"*, "L Nickel"*, "Monel"*, "K Monel"*, "Inconel"*, 30% Cupro Nickel.

Beryllium Copper:

*Reg. U. S. Trademark International Nickel Company



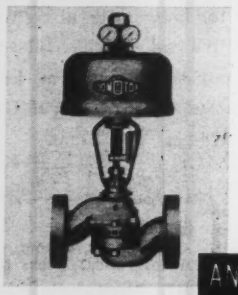
You can cut

[redacted]

by over 50% with

ANNIN VALVES

Designed for maximum interchangeability of valve bodies, flanges and operators

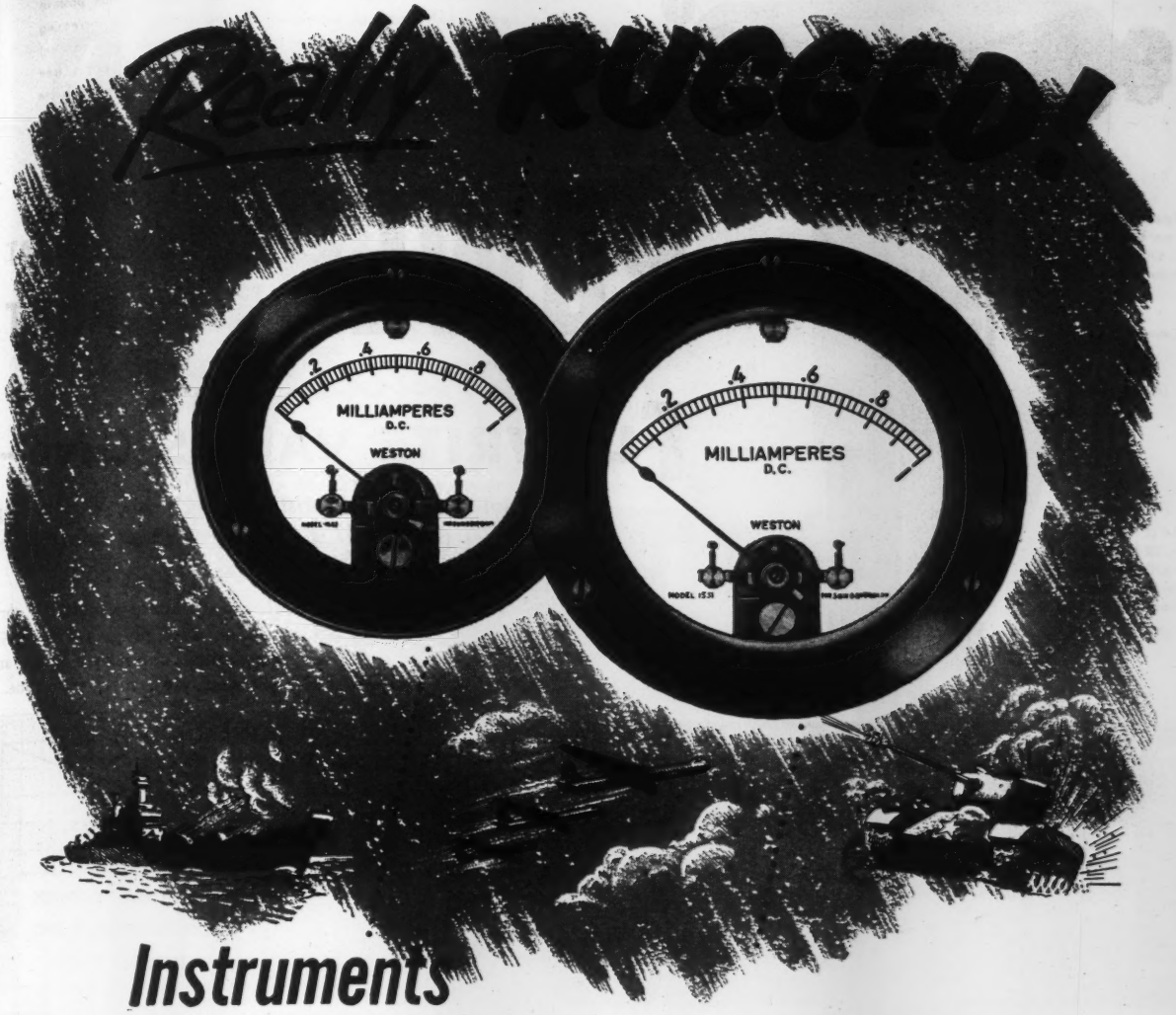


The Annin Domotor valves provide positive control of corrosive, erosive fluids and fluids containing semi-solids.

Because all Annin valve bodies carry 1000# ratings, interchangeable flanges in Series 15, 30 and 60 can be mounted with split-rings on any Annin valve body to meet the requirements of practically any installation. One body, mounted with proper flanges, can be used anywhere in the plant. In addition, any Annin operator—Domotor, Electro-Pneumatic, Handwheel—fits *two* sizes of any valve body. Thus it is unnecessary to stock spares for *every* valve type and size you use. Most Annin users report great reductions in necessary valve stocks from 50% to 75% and more!

This reduction in inventory, *plus* considerable reductions in maintenance costs make the Annin Valve one of the most economical to operate in your plant. It will pay you to investigate today the many advantages of Annin Control Valves. Send for Catalog 1500B.

Annin Catalog 1500B describes all Annin Valves, tells how Annins reduce inventories and cut maintenance costs. Send for your copy *today!*



Instruments RUGGEDIZED by WESTON

Especially designed and built to meet the severe requirements of the specification for ruggedized instruments, MIL-M-10304. (Sig. C.)

Real *ruggedizing* has been obtained not merely by stoutening and shock-mounting the instrument components . . . but by entirely *new designs,* employing *new materials* and *new techniques* developed especially for this purpose.

The result is an instrument that will continue functioning dependably under severe conditions of shock, vibration, temperature and humidity . . . conditions heretofore considered beyond the capabilities of such devices.

WESTON RUGGEDIZED INSTRUMENTS are available as *d-c voltmeters, ammeters, milliammeters and microammeters* in 2½" and 3½" sizes. Information on request. WESTON Electrical Instrument Corporation, 617 Frelinghuysen Avenue, Newark 5, New Jersey, *manufacturers of Weston and TAG instruments.*

9147 **WESTON** *Instruments* ...INDICATE—RECORD—CONTROL

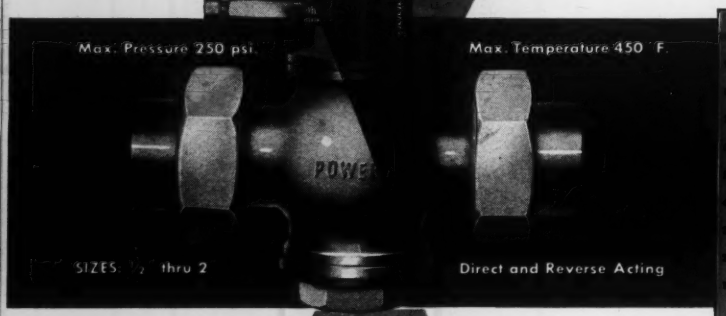
VALVE TOP—Durable moulded neoprene diaphragm (1) has positive sealing bead which provides increased sealing action with increasing control pressure. Efficient diaphragm form insures ample and constant operating power thru full travel. Piston Plate Assembly (2) has a free floating thrust plate which absorbs side thrust. Closely guided piston plate maintains stem in accurate alignment. Maximum air pressure in top, 22 psi.

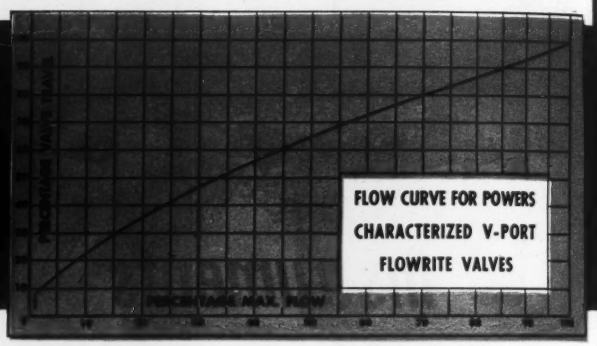
POWERS® SINGLE SEAT V-PORT *Characterized* FLOWRITE VALVES Give-

Special Cast Iron [illegible] and Top Only 4 [illegible]

Compressed Air or Water Operated

BALL CHECK LUBRICATOR SILICONE grease for temperatures from 40° to 500° F.



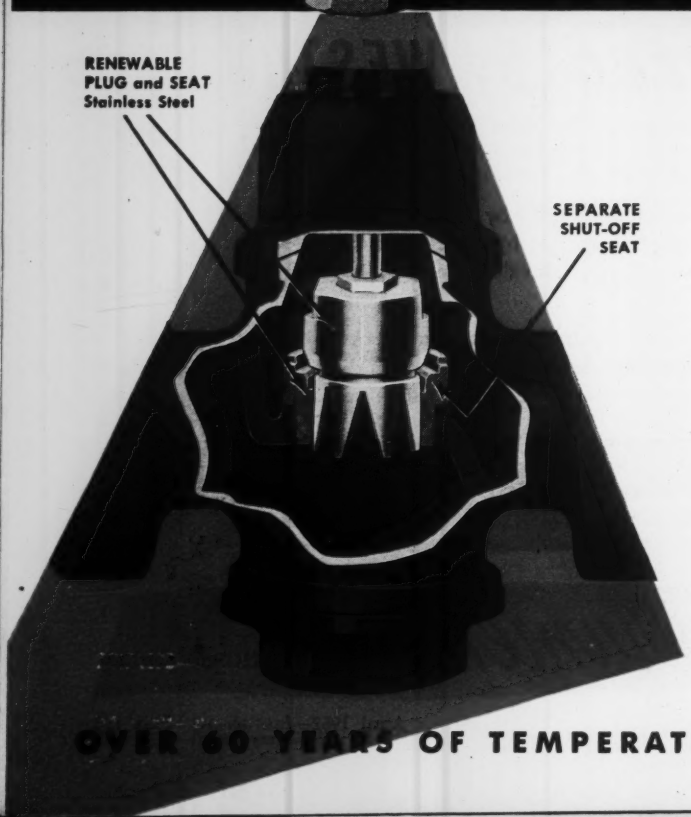


Special Flow Characteristics—High lift V-Port plug provides proportional flow throughout entire lift of stem as shown in chart below.

Wide Variety of Valve Sizes—Nine sizes are available, ½" thru 2". The ½" valve can be furnished with plugs to give 15%, 30%, 60% or 100% of maximum capacity. Plugs are easily interchangeable without removing valve from line.

RENEWABLE PLUG and SEAT Stainless Steel

SEPARATE SHUT-OFF SEAT



Better Control—Less Maintenance—Superior design of stainless steel plug and seat reduces wire drawing, insures longer life and tight shut off. V-Ports do the throttling, protecting separate shut off seat. Plug and seat are truly removable and can be easily replaced in the field. Inner valves are machined and precision ground and lapped within very close tolerances.

Low Hysteresis—Due to smooth rolling diaphragm and polished stainless steel stem in preformed lubricated packing.

Easy to Adjust—Ball bearing adjusting screw; rust proofed steel calibrated springs with full travel in 5 or 10 psi.

Easy to Install—Powers Flowrite V-Port valves have double unions and bronze body with rugged construction to withstand piping strains.

Easy to Service—Valve and top are easy to take apart and re-assemble, facilitating inspection and maintenance.

Reasonably priced. Contact our nearest office for prices and assistance in selecting proper size valves

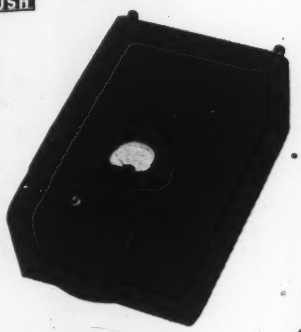
THE POWERS REGULATOR CO.

SKOKIE, ILLINOIS • Offices in Over 50 Cities

Chicago 13, Ill., 3819 N. Ashland Ave. • New York 17, N. Y., 231 E. 46th Street
Los Angeles 5, Cal., 1808 West 8th Street • Toronto, Ontario, 195 Spadina Ave.
Mexico, D. F., Apartado 63 Bis: • Honolulu 3, H. I., P. O. 2755—450 Piikoi at Kona

OVER 60 YEARS OF TEMPERATURE AND HUMIDITY CONTROL

Speed up analysis with these Brush instruments

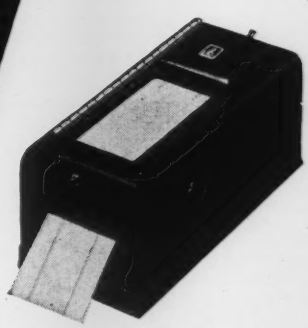


Direct-coupled Amplifier
Model BL-932

AMPLIFIES VERY LOW VOLTAGES. The Brush Direct-coupled Amplifier features high sensitivity and low drift. When used in conjunction with the Brush Magnetic Oscillograph, it gives one chart millimeter deflection per millivolt input. Design features reduce effects of power line fluctuation. Zero signal drift not more than one chart millimeter per hour. Frequency response essentially uniform from d-c to 100 cycles.

When used with the Brush Magnetic Oscillograph, the Amplifier can be used to record phenomena previously requiring the use of complicated intermediate equipment. Analysis of static or dynamic conditions involving either high or low signal strength is simplified and speeded with this equipment. Below, it is shown recording time constants of a reactor to provide a saturation curve.

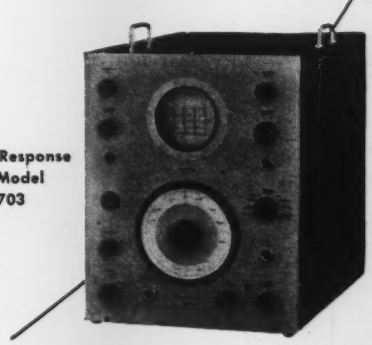
PROVIDES IMMEDIATE RECORDING. The Brush Magnetic Oscillograph, used with the proper Brush Amplifier, makes a direct chart recording of physical phenomena which is immediately available. Either direct inking or electric stylus models available. Gear shift provides chart speeds of 5, 25, and 125 mm per second. An auxiliary chart drive is available for speeds of 50, 250, and 1250 mm per hour. Accessory equipment provides event markers where an accurate time base is required, or where it is desirable to correlate events. Photo shows two-channel model for recording of two phenomena simultaneously.



Direct-writing Two-Channel
Magnetic Oscillograph Model BL-202

CHECKS FREQUENCY RESPONSE QUICKLY. The Frequency Response Tracer permits visual examination of frequency response characteristics of radio receivers, amplifiers, transmission lines, filters. Electro-acoustic investigation of loudspeakers, microphones, and telephones can be made. Frequency range is 20 to 20,000 cycles, logarithmic scale. Continuous motor drive scans entire frequency range in 8 seconds.

Write for free copy of Bulletin 618 giving details on these Brush instruments. The Brush Development Company, Dept. A-24, 3405 Perkins Ave., Cleveland 14, Ohio. In Canada: A. C. Wickman Limited, Box 9, Station N, Toronto.



Frequency Response
Tracer Model
BL-4703

PUT IT IN WRITING WITH A BRUSH RECORDING ANALYZER

THE Brush DEVELOPMENT CO.

PIEZOELECTRIC CRYSTALS AND CERAMICS • MAGNETIC RECORDING
ACOUSTIC DEVICES • ULTRASONICS • INDUSTRIAL & RESEARCH INSTRUMENTS

Need permanent magnets and expert magnet services?

Substantial supplies of Carboloy Alnico permanent magnets now available for most D.O.-rated applications

CARBOLOY magnet engineers are experts at designing assemblies with circuits that provide more useful energy with less magnetic material. Their services are yours when you need help in magnet design and application.

TWO helpful bulletins are yours for the asking: a clear, informative Permanent Magnet Design Manual with latest technical data, and the newly released catalog of Stocked Carboloy Alnico Permanent Magnets. Send coupon for your free copies.

Substantial, increasing quantities of Carboloy Alnico permanent magnets are now available to all plants that can extend their D.O. ratings under C.N.P. Regulation No. 3. For nearly all applications except toys, novelties and a few other accepted uses, you can plan to use magnets for modernization of present products, new products in the experimental stage or expanded production of present applications. Carboloy magnets are available in cast or sintered form . . . will be job-designed and built to your specifications or furnished from standard stocks.

And, as always, experienced Carboloy magnet engineers will assist you in magnet design and application. Their skills with Carboloy Alnico magnets may supply just the extra touch you need to help you improve that meter, motor, instrument, control, generator, magneto, TV speaker or whatever product you produce.

Guaranteed Energy

You'll get superior magnets, too. Carboloy magnets are built under the most rigid controls practiced anywhere. They are checked and tested for quality and uniformity, and each one is *guaranteed* to meet or surpass the industry's external energy minimum.

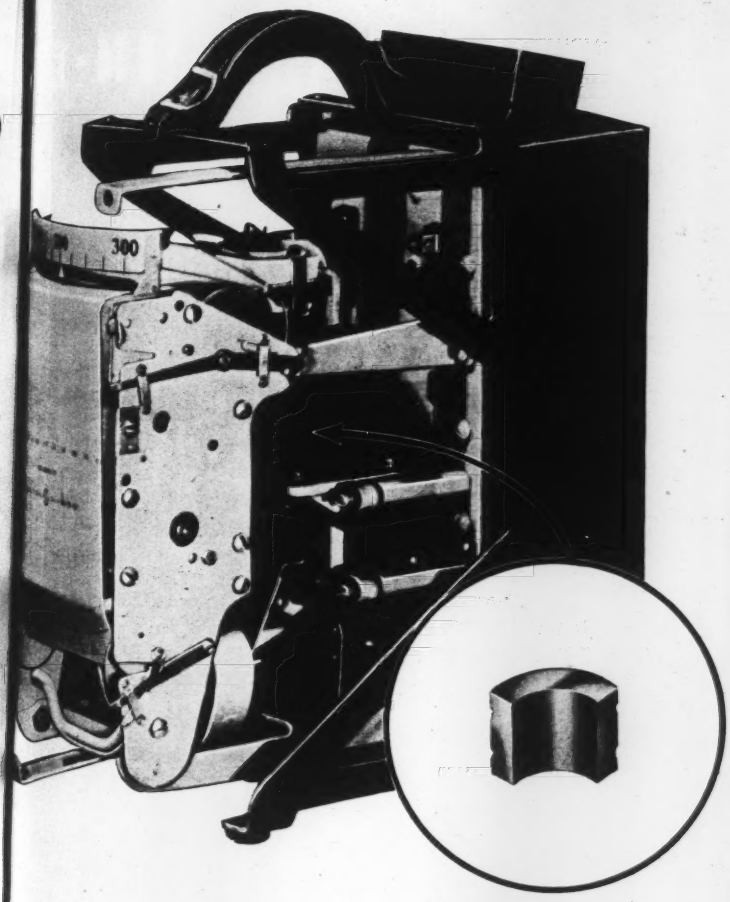
Get in touch with us today. From design to *delivery on the day promised,* we'll do everything possible to give you service and satisfaction . . . *plus* the magnets you need to make your products better, your profits greater.

"Carboloy" is the trademark for the products of Carboloy Department of General Electric Company

CARBOLOY

DEPARTMENT OF GENERAL ELECTRIC COMPANY

11155 East Eight Mile Street • Detroit 32, Michigan



METERS and instruments are but one of the many fields where permanent magnets work wonders. In the Current Recorder above, a concentric magnet element of Carboloy Alnico is the measuring mechanism. Being small in size, but tremendously powerful, it simplified the design . . . reduced the recorder's weight by 10 pounds . . . greatly contributed to its sensitivity and accuracy. Here is a typical case where modernization through permament magnets pays off in improved products.

CARBOLOY

ALNICO PERMANENT MAGNETS

Designed Right . . . Built Right . . . Delivered Right on Time and with Energy-Potential Right!

GET THESE 12 OUTSTANDING ADVANTAGES! SPECIFY CARBOLOY PERMANENT MAGNETS

1 **SIMPLE**—Compact, self-containing sources of energy with no operating parts.

2 **UNIFORMLY POWERFUL**—Guaranteed to meet or surpass the standard external energy minimum.

3 **LAST FOREVER**—Will supply a constant, uniform magnetic field indefinitely.

4 **NO WIRING**—Eliminate need for coils, windings, or other electrical fixtures.

5 **COOL-RUNNING**—Won't generate heat; need no provisions for heat dissipation.

6 **NO OPERATING COSTS**—Operate without maintenance costs or any power supply.

7 **NO POWER FAILURES**—There is no outside source of power to fail!

8 **COMBINE ELECTRICAL AND MECHANICAL FEATURES**—Transform electrical energy into mechanical motion; mechanical motion to electrical energy.

9 **SIMPLIFY MECHANICAL ASSEMBLIES**—Exert strong tractive force for holding, lifting and separating devices that eliminates component parts, makes product design and fabrication extremely simple.

10 **UNINTERRUPTED OPERATION**—Magnetic energy flows *continually* and *forever!*

11 **CREATE SAVINGS**—Reduce weight, save space, lower cost of fabricating and eliminate other, often more costly, power-supplying parts.

12 **MOISTURE-RESISTANT**—No coils to collect moisture.

Clip and Mail Today!

CARBOLOY
Department of General Electric Company
11155 East Eight Mile Street, Detroit 32, Michigan

I am interested, **without obligation**, in receiving information about the 12 outstanding advantages of Carboloy Alnico Permanent Magnets.

☐ Send me free copies of Design Manual and Standard Stock Catalog.

☐ Have a Carboloy magnet engineer call at my plant soon.

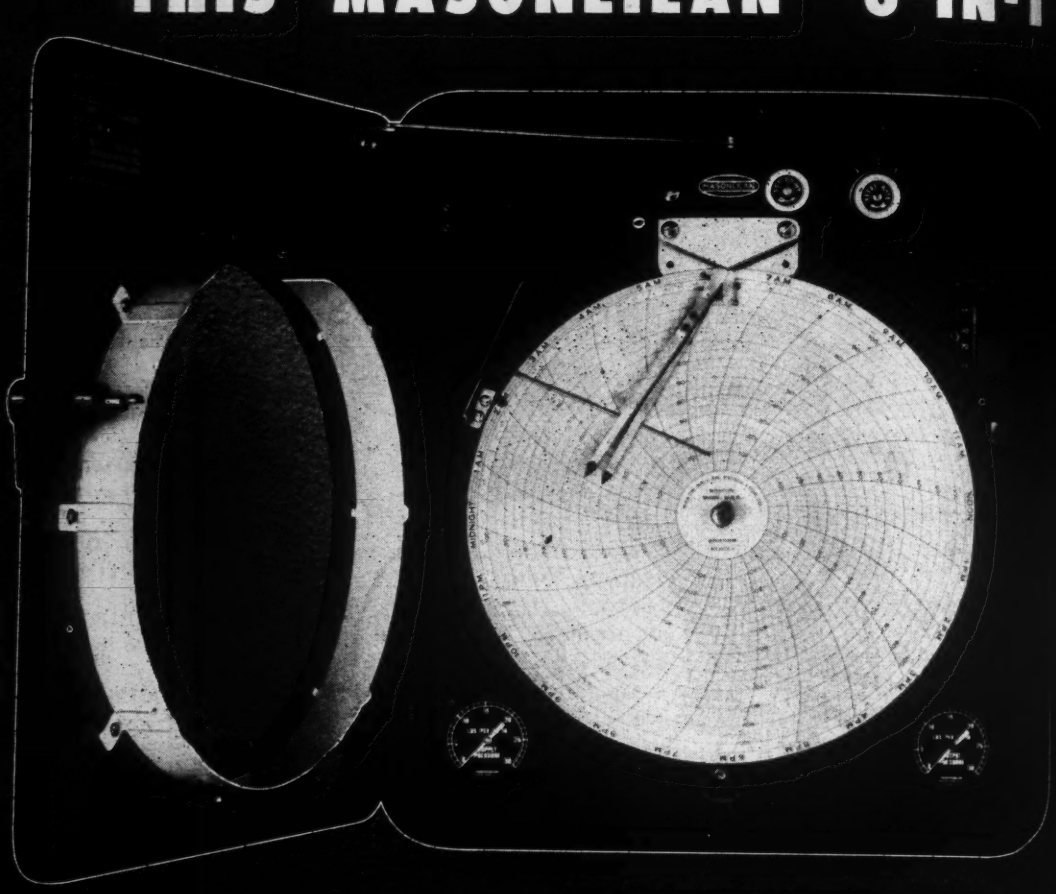
Name_____ Position_____

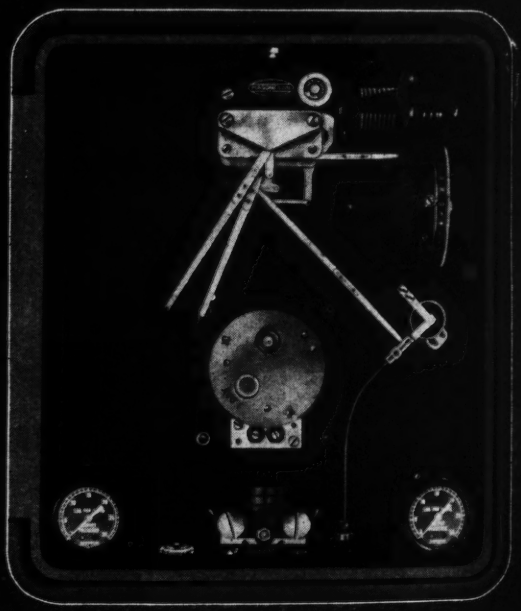
Company Name_____

Address_____

City_____ Zone____ State_____

THIS MASONEILAN "6-IN-1 C





MASONEILAN
60000 SERIES
PNEUMATIC CONTROLLER

A HIGH C_Q PRODUCT

...CONTROLLER GIVES YOU

...Because of its COMPLETE SIMPLICITY

Masoneilan engineers "designed out" the complications which have previously been headaches to you — and "designed in" a simplicity which you will welcome. You can rely on these instruments to give you unfailing performance — and unexcelled performance — day after day . . . because trouble spots just don't exist.

Consider the advantages the simplicity of this really modern design offers you . . .

1. ONE MECHANISM — the GIMBAL UNIT — provides four combinations of primary and feedback motion to give you a choice of SIX TYPES OF CONTROL: Direct Proportional; Reverse Proportional; Direct Differential-Gap; Reverse Differential-Gap; Direct On-Off and Reverse On-Off.

2. ONE SETTING selects type of control, type of action and proportional band or differential-gap setting.

3. COMBINATION BACKPLATE-MANIFOLD supports all operational units (plus chart drive and gauges); supports and conceals pneumatic tubing with plug-in connections, which eliminate pressure fittings.

4. Complete, INDEPENDENT operational unit SUBASSEMBLIES — relay pilot, primary element, pen movement gimbal unit, and proportional (or proportional-reset) unit — are *easily* ACCESSIBLE, *easily* INTERCHANGEABLE. Only TWO LINKS are used for connections.

5. SETTINGS (made by knurled knobs and large proportional band wheel) and pilot METERING TUBE are ACCESSIBLE WITHOUT REMOVING CHART.

All types of control plus pneumatic set, time cycle and differential supplementary functions are now available in recording or indicating controllers for pressure, temperature, liquid level or flow service. Also recorders and manual control subpanel.

MASON-NEILAN REGULATOR CO.
1210 ADAMS STREET, BOSTON 24, MASS., U.S.A.

Sales Offices or Distributors in the Following Cities: New York • Syracuse • Chicago • St. Louis • Tulsa
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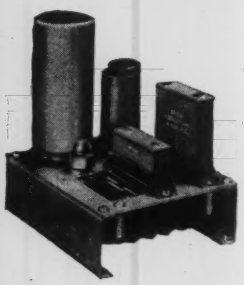
MASONEILAN

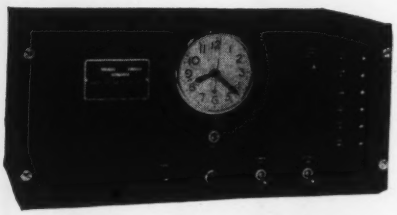


TYPE 2001-2, BASIC UNIT

Frequencies 200 to 2500 cycles. Dividers and Multipliers available for lower and higher frequencies. Miniaturized and JAN construction. Output, 6 volts.

TYPE 2005, UTILITY UNIT

Consists of Type 2001-2 and booster to provide 10 watts at 110V at precision frequencies from 50 to 500 cycles at input power frequencies of 50 to 500 cycles, 45 watts.



TYPE 2121-A, LAB. STANDARD

Outputs, 60 cycle, 0-110 Volts, 10 Watts; 120-240 cycle impulses. Input, 50-400 cycles, 45 Watts.

Precision FREQUENCIES

GUARANTEED ACCURATE TO 1 PART IN 100,000 (.001%)

TYPE 2111, POWER UNIT

50 Watt output. 0-110-220V at 60 cycles, or any frequency 50 to 1000 cycles. Input, 50-100 cycles, 275 watts.

THE basis of these frequency standards is an electronic fork which is temperature-compensated and hermetically sealed against humidity and barometric pressure.

Type 2001-2 and similar units are available independently. Complete instruments of our manufacture are used extensively by industry and the armed forces where unvarying, dependable high precision is required, such as for bombsights and fire control.

WIDELY USED IN SUCH FIELDS AS:

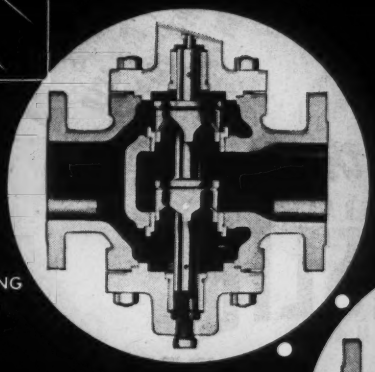
Aviation
Astronomy
Ballistics
High-Speed Photography
Viscosity Measurement
Nuclear Physics
Telemetering
Radiation Counting
Fluid Flow
Chemical Reaction
Navigation
School Laboratories
Industrial Research Labs.
Accurate Speed Control

WHATEVER YOUR FREQUENCY PROBLEMS, OUR ENGINEERS ARE READY TO COOPERATE. PLEASE REQUEST DETAILS BY TYPE NUMBER.

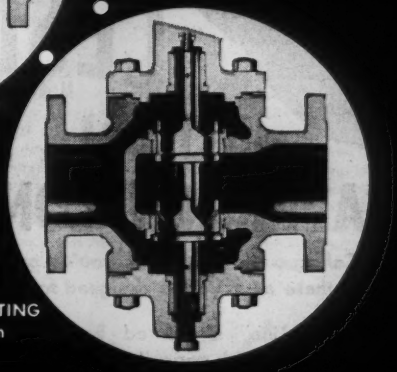
American Time Products, Inc.

580 Fifth Avenue OPERATING UNDER PATENTS OF WESTERN ELECTRIC COMPANY ***New York 19, N. Y.***

QUICK SHIFT

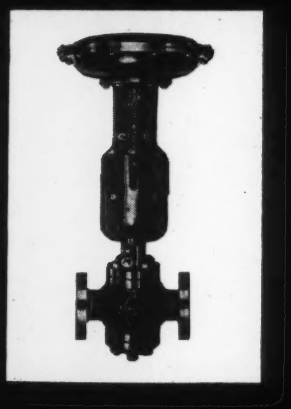


DIRECT ACTING
air to close



REVERSE ACTING
air to open

for easy field reversal of valve action



You can reverse the control action of the Honeywell Series 700 Valve by inverting the valve body and disc, and turning the travel indicator plate to its reverse side. It can be done in the field . . . easily and quickly, without extra parts or complex adjustments.
The Honeywell Series 700 wide band proportional control valve comes in a full range of styles and sizes . . . has *all* the features you look for in a fine valve.
Write today for your copy of Bulletin 700-2.

MINNEAPOLIS-HONEYWELL REGULATOR CO., *Industrial Division,* 1908 Windrim Avenue, Philadelphia 44, Pa.

MINNEAPOLIS
Honeywell
VALVE PRODUCTS

H
HONEYWELL

First in Controls

You've got a Winning Combination

...with the New TRADE LESLIE MARK

DOUBLE SEATED DIAPHRAGM CONTROL VALVES

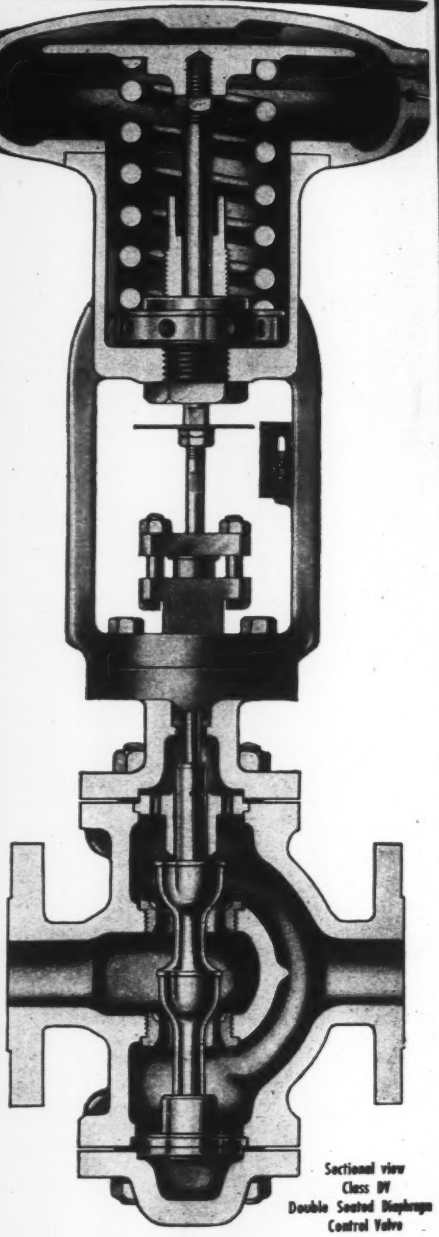
Calling a spade a spade you've got a "royal flush" of features in these new Valves designed for use with control instruments.

Their "Flow-Line" Contoured Bodies have ISA standard face-to-face dimensions and high capacity, low turbulence and minimum body pressure drop characteristics.

A new type, top and bottom guided construction is self-aligning and non-binding regardless of uneveness of bolt tightening.

Standard, integral stellited seating surfaces are recommended for steam service to reduce seat ring thread corrosion. Renewable, interchangeable seat rings also furnished where desired and may be easily replaced without removing valve body from the line. Elaborate grinding at high temperatures is completely eliminated.

With these Valves, you get as *standard equipment*, features heretofore only obtainable in expensive, specially designed valves.



Sectional view Class DV Double Seated Diaphragm Control Valve

Look for LESLIE REGULATORS under "Valves" or "Regulators" in your classified telephone directory in the following cities where LESLIE factory trained engineers are located:

Albany, N. Y.	Chicago, Ill.	Galveston, Tex.	Memphis, Tenn.	Orlando, Fla.	Salt Lake City, Utah
Albuquerque, N. M.	Cincinnati, Ohio	Greenville, S. C.	Miami Springs, Fla.	Philadelphia, Pa.	San Francisco, Calif.
Atlanta, Ga.	Cleveland, Ohio	Houston, Texas	Milwaukee, Wis.	Pittsburgh, Pa.	Seattle, Wash.
Baltimore, Md.	Dallas, Texas	Indianapolis, Ind.	Minneapolis, Minn.	Ponca City, Okla.	St. Louis, Mo.
Beaumont, Tex.	Denver, Colo.	Kansas City, Mo.	Mobile, Ala.	Providence, R. I.	Syracuse, N. Y.
Birmingham, Ala.	Des Moines, Ia.	Kingsport, Tenn.	Monroe, La.	Richmond, Va.	Tucson, Ariz.
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***WRITE FOR* Bulletin 513**

ESTABLISHED 1900 LESLIE CO.

299 Grant Avenue, Lyndhurst, New Jersey

1707

FLOATLESS LEVEL CONTROLS • PUMP GOVERNORS • TEMPERATURE REGULATORS
SELF CLEANING STRAINERS • AIR HORNS • STEAM WHISTLES
PRESSURE REDUCING VALVES • PRESSURE CONTROLLERS

International
RECTIFIER
CORPORATION
EL SEGUNDO
CALIFORNIA

Selenium Diodes

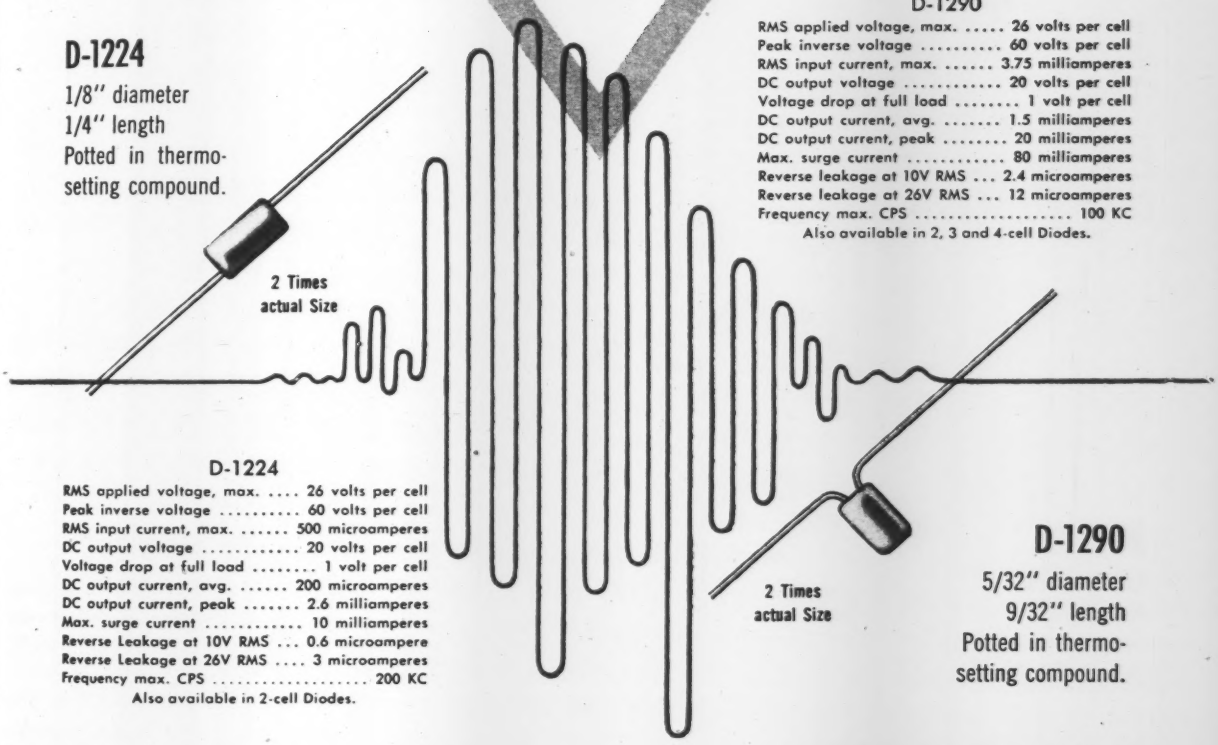
D-1290

RMS applied voltage, max. ..... 26 volts per cell
Peak inverse voltage ..... 60 volts per cell
RMS input current, max. ..... 3.75 milliamperes
DC output voltage ..... 20 volts per cell
Voltage drop at full load ..... 1 volt per cell
DC output current, avg. ..... 1.5 milliamperes
DC output current, peak ..... 20 milliamperes
Max. surge current ..... 80 milliamperes
Reverse leakage at 10V RMS ... 2.4 microamperes
Reverse leakage at 26V RMS ... 12 microamperes
Frequency max. CPS ..... 100 KC
Also available in 2, 3 and 4-cell Diodes.

D-1224

1/8" diameter
1/4" length
Potted in thermo-setting compound.

2 Times actual Size



D-1224

RMS applied voltage, max. .... 26 volts per cell
Peak inverse voltage ..... 60 volts per cell
RMS input current, max. ..... 500 microamperes
DC output voltage ..... 20 volts per cell
Voltage drop at full load ..... 1 volt per cell
DC output current, avg. ..... 200 microamperes
DC output current, peak ..... 2.6 milliamperes
Max. surge current ..... 10 milliamperes
Reverse Leakage at 10V RMS ... 0.6 microampere
Reverse Leakage at 26V RMS .... 3 microamperes
Frequency max. CPS ..... 200 KC
Also available in 2-cell Diodes.

2 Times actual Size

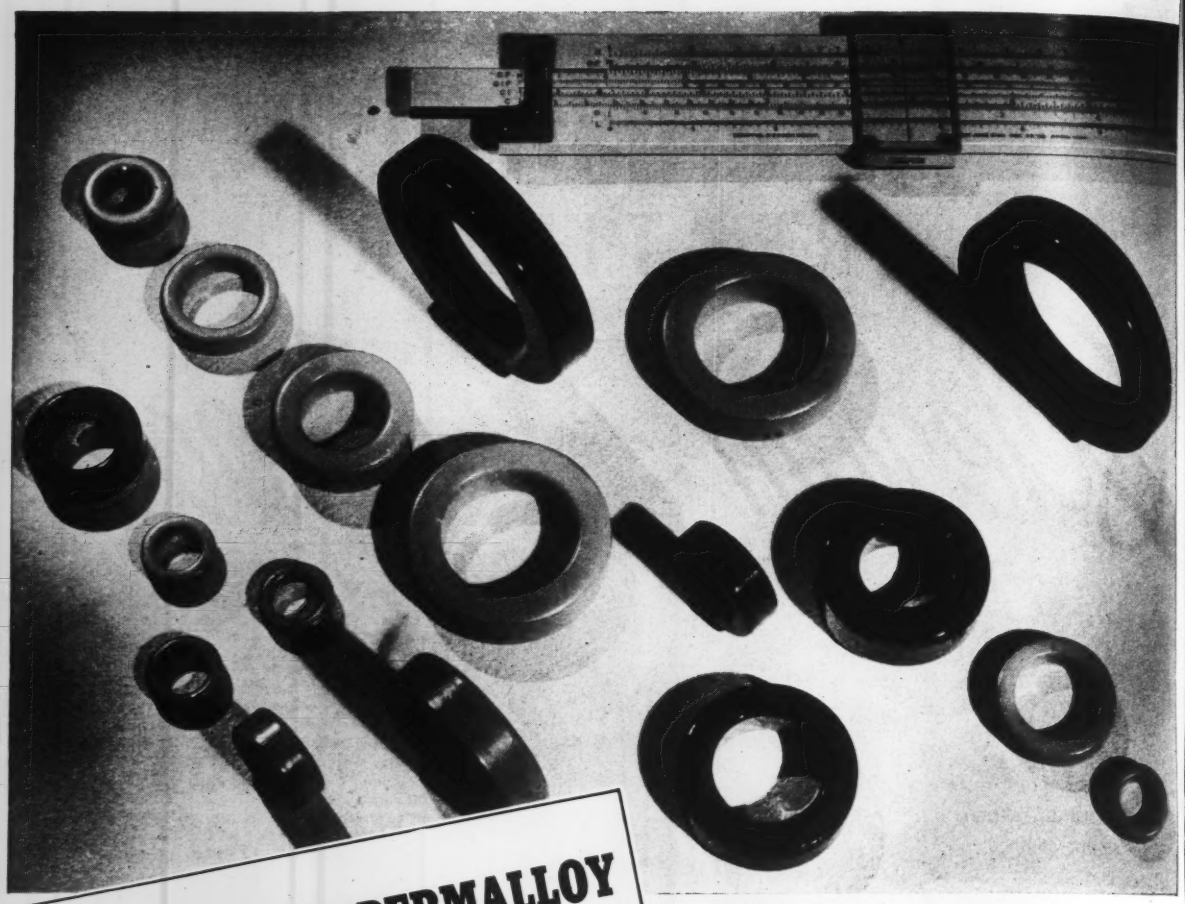
D-1290

5/32" diameter
9/32" length
Potted in thermo-setting compound.

International
RECTIFIER CORPORATION

GENERAL OFFICES:
1521 E. Grand Ave.
El Segundo, Calif.
Phone El Segundo 1890

CHICAGO BRANCH OFFICE:
205 W. Wacker Dr.
Franklin 2-3889



MOLYBDENUM PERMALLOY POWDER CORES*

(New technical data now available)

HIGH Q TOROIDS for use in Loading Coils, Filters, Broadband Carrier Systems and Networks—for frequencies up to 200 KC

COMPLETE LINE OF CORES TO MEET YOUR NEEDS

★ **Furnished in four standard permeabilities—125, 60, 26 and 14.**

★ **Available in a wide range of sizes to obtain nominal inductances as high as 281 mh/1000 turns.**

★ **These toroidal cores are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.**

For high Q in a small volume, characterized by low eddy current and hysteresis losses, ARNOLD Moly Permalloy Powder Toroidal Cores are commercially available to meet high standards of physical and electrical requirements. They provide constant permeability over a wide range of flux density. The 125 Mu cores are recommended for use up to 15 kc, 60 Mu at 10 to 50 kc, 26 Mu at 30 to 75 kc, and 14 Mu at 50 to 200 kc. Many of these cores may be furnished stabilized to provide constant permeability (±0.1%) over a specific temperature range.

*Manufactured under license arrangements with Western Electric Company

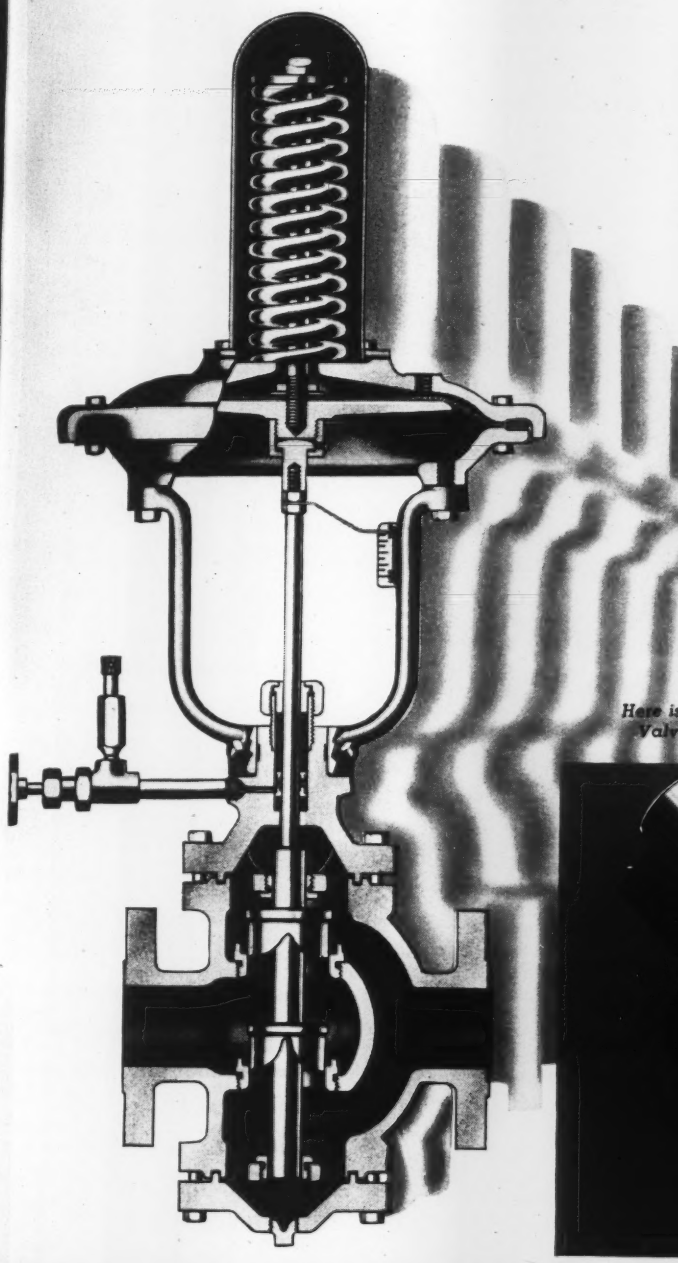
WAD 4127

THE ARNOLD ENGINEERING COMPANY

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

LET 60,000 INSTALLATIONS GUIDE YOU TO BETTER PROPORTIONAL CONTROL



Optimum flow characteristics, coupled with free-floating, self-aligning motor action, have made "Stabilflo" the most preferred name in control valves. Ever since the development of proportional control, critical users have depended upon these wide-range V-port valves for the utmost in performance.

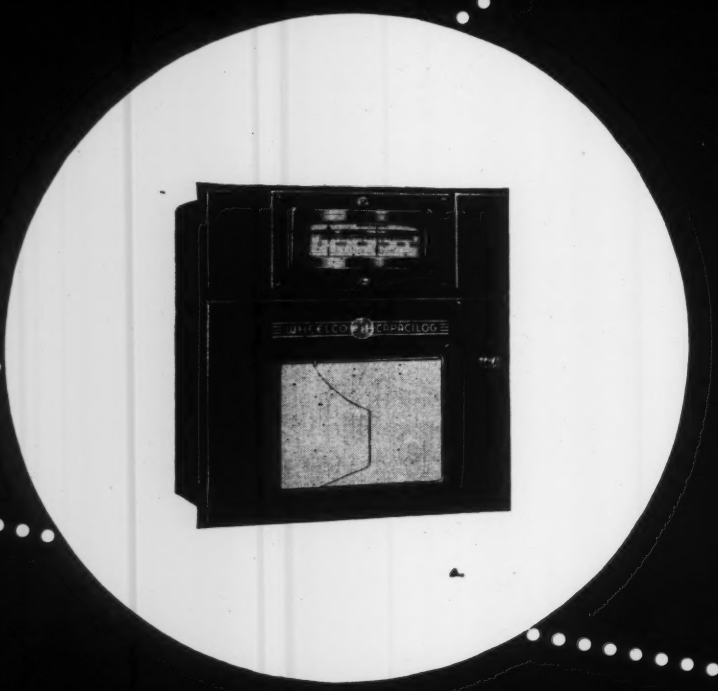
Because of their unique port design, Stabilflo Valves give very precise "equal percentage" flow relations throughout the range from 2 to 100% of flow. Their rangeability is 50-to-1. With these valves, you can be sure that the extraordinary sensitivity, accuracy and dependability of modern proportional controllers are translated into matching valve performance. Get the details in Bulletin 277-2. Write **The Foxboro Company, 464 Neponset Ave., Foxboro, Mass., U. S. A.**

Here is the Foxboro Exponential Port that gives Stabilflo Valves their unique equal percentage characteristic.

FOXBORO
REG. U. S. PAT. OFF.

STABILFLO CONTROL VALVES

FACTORIES IN THE UNITED STATES, CANADA AND ENGLAND



VERSATILE
variety of control

SIMPLE
interchangeable assemblies

ACCURATE
¼ of 1% of full scale

ECONOMICAL
low original cost

For complete information on custom recording at "mass production" prices, ask for CAPACILOG BULLETIN C2. Wheelco Instruments Company, 835 West Harrison Street, Chicago 7, Illinois.

How CROSBY'S BALANCED AREA DESIGN eliminates back pressure effects

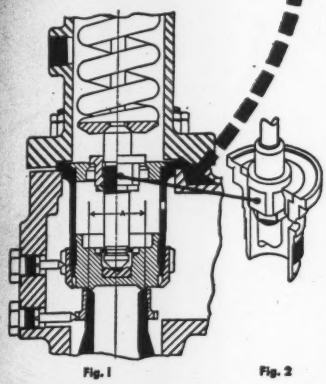


Fig. 1 Fig. 2

When a standard relief valve on gas or vapor service is installed, where back pressure exists, one of two undesirable effects will occur:

Constant Back Pressure — The back pressure acts on part of the upper and the overhanging part of the lower surface of the disc, cancelling out the back pressure force. There remains, however, a force acting on the top portion of disc (area A) which increases the spring load and causes the valve to pop "heavy."

Variable Back Pressure can not be compensated for by spring adjustments. When one or more valves discharge into a common flare header, variable back pressure is placed on the remaining closed valves. This can create a hazardous condition on remaining closed valves, by adding to the spring force. The valve then is prevented from opening until pressure has risen far above the vessel design limit.

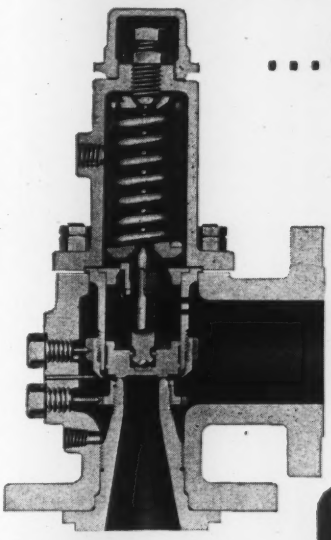
[redacted] is a simple, foolproof method of nullifying these undesirable effects (see Figure 1 above).

Operation — Crosby achieves *Stable Popping Pressure* by the addition of a piston affixed to the spindle, of area proportioned to equal the unbalanced area of the disc (area A in Fig. 1). Back pressure introduced through the port in the guide then acts on two equal areas in opposite directions, and cancels itself out, neither aiding nor opposing the spring.

To assure full lift and stability, a vent system (see sectional view of piston, Fig. 2) is employed. When the valve is open, the flats on the piston will vent any accumulated back pressure that would tend to close the valve. The adjustment and operating characteristics are similar to the conventional valve. The actual flow into the bonnet is relatively low and can be vented to atmosphere, or through a properly sized discharge header.

Extensive, trouble-free use in the field has proved the success of this Crosby Balanced Area Design.

Here's the [redacted] RELIEF VALVE which eliminates back pressure effects ...and reduces costs!



CROSBY RELIEF VALVE
Style JO-BP
with BALANCED AREA DESIGN
for the elimination
of Back Pressure Effects.

Proved ECONOMY!

On the many installations where Crosby JO-BP Valves have been in operation, refineries report sizable savings in piping costs. The reason—smaller discharge lines made possible by higher back pressure. Since Crosby JO-BP Relief Valves will handle back pressure surges ranging up to 90% of inlet pressure, smaller diameter discharge pipe carries the same amount over the same distance that formerly required much larger pipe.

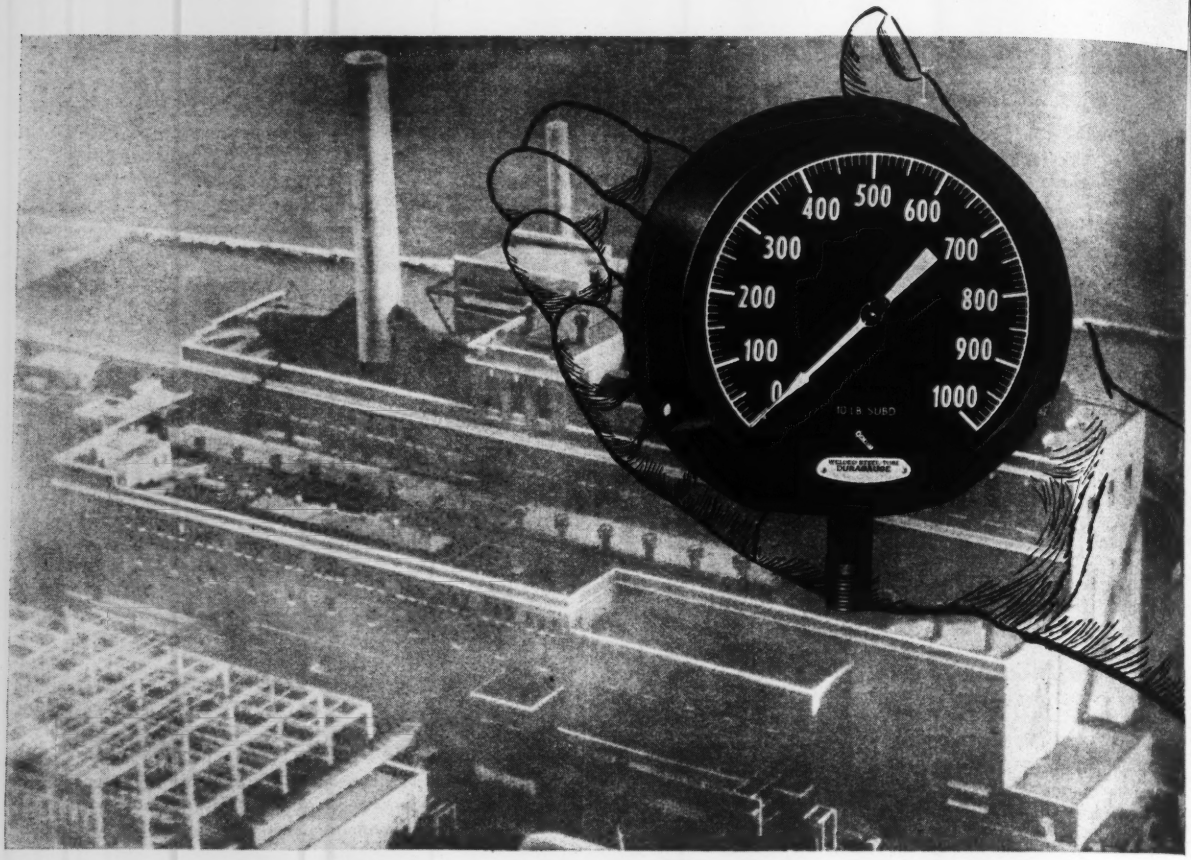
Proved PROTECTION!

On-the-job performance of Crosby JO-BP Relief Valves proves that you can depend on the vented Balanced Area Design to operate on the set pressure. Thus you are assured of a *Stable Popping Point*. What's more, a full lift is obtained over the normal range of back pressures. The Crosby JO-BP operates with an unrestricted nozzle, follows standard nozzle flow equations for above or below critical ratio as the case may be. With its vented Balanced Area Design, the Crosby JO-BP provides a foolproof, time-tested method of eliminating back pressure effects.

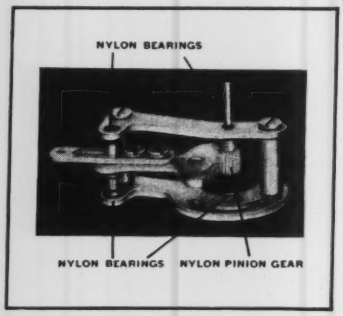
CROSBY STEAM GAGE & VALVE COMPANY

43 Kendrick Street, Wrentham, Mass.

District Sales Offices:
BOSTON · NEW YORK · CHICAGO · DALLAS · LOS ANGELES



Outlasts ALL OTHERS!



Since the introduction of the Nylon Movement* in 1947, the Ashcroft Duragauge has set new standards for pressure gauge performance in the most "killing" services.

Here's why: All worthless weight and mass of parts is engineered *out* of the Duragauge Nylon Movement. The light, strong, dimensionally stable nylon pinion gear and bearings have low coefficients of friction. They absorb vibration and pulsation—resist wear—far better. All this adds up to sustained accuracy, improved sensitivity, lower maintenance and longer service life.

Whether you generate electricity, refine petroleum, process chemicals or anything else demanding accurate pressure indication or recording to insure safety, product quality, or cost control – install Ashcroft Duragauges. Your nearby Ashcroft Distributor will gladly help you select the right Ashcroft Duragauge for your specific needs

*Patented

ASHCROFT 1850 U.S.A.

ASHCROFT GAUGES

MAXWELL MANNING M&M MOORE INC. TRADE MARK

A product of **MANNING, MAXWELL & MOORE, INC.** STRATFORD, CONNECTICUT

MAKERS OF 'ASHCROFT' GAUGES, 'HANCOCK' VALVES, 'CONSOLIDATED' SAFETY AND RELIEF VALVES, 'AMERICAN' INDUSTRIAL INSTRUMENTS. BUILDERS OF "SHAW-BOX" CRANES, 'BUDGIT' AND 'LOAD LIFTER' HOISTS AND OTHER LIFTING SPECIALTIES.

STAYNEW

ABSORPTION FILTERS PROVIDE

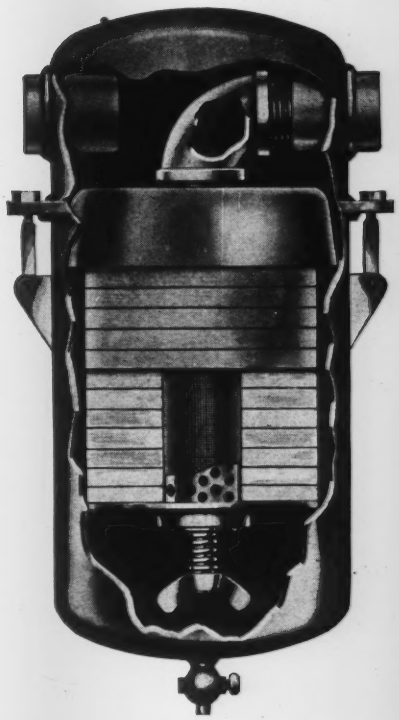
SUPER FILTRATION!

—REMOVE LAST TRACES OF OIL AND MOISTURE FROM COMPRESSED AIR LINES

The model AAPH Absorption Type Filter has proven itself to be the real answer to the elimination of costly service interruptions in utility and industrial power plants. Many manufacturing processes and certain compressed air operated equipment require the removal of condensed oil and water vapors *completely* from the compressed air. In thousands of installations all over the country, Staynew Absorption Filters remove the last traces of oil and moisture and prevent failure of combustion and other pneumatic controls . . . keep maintenance time and cost at a minimum.

For Complete Information, Write Today For Bulletin B-1A

Representatives in Principal Cities



MODEL AAPH
Absorption Filter

DOLLINGER
REG. PROTECTOMOTOR U.S. PAT. OFF.
STAYNEW FILTERS

DOLLINGER

CORPORATION

63 Centre Pk., Rochester 3, N. Y.

ALL TYPES OF FILTERS FOR EVERY INDUSTRIAL NEED

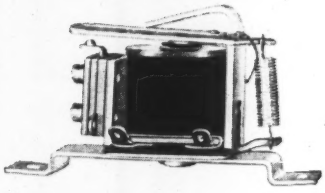
for RADAR BEAM OR TRAFFIC CONTROL

Relays BY GUARDIAN

"SPOT" YOUR CONTROL PROBLEMS

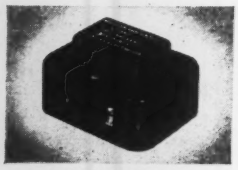
Small . . . to save weight and space in radar and guided missile equipment, Guardian Relays prove that quality still comes in small packages. Basic . . . flexible . . . government approved . . . Guardian Relays are ruggedly built and *hermetically sealed* to withstand every atmospheric condition, including the rigors of supersonic flight. Guardian Relays, specified in devices that count—detect—indicate—direct—shoot—convey—compute—sort—package—vend—meter—hold the answer to your control problem. Write.

This unit tabs 900 or more overlapping cars per minute at split-second contact. As car wheels hit a pneumatic tube stretched across traffic lanes the compression closes an electrical contact on a diaphragm, operating a Guardian Series 125 D.C. relay. The relay responds to every impulse but the counter unit registers only every other impulse to compensate for rear wheel contact.



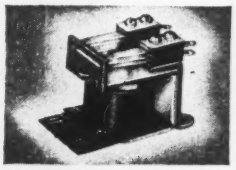
SERIES 125 D.C. RELAY

AN-3320-1 D.C.

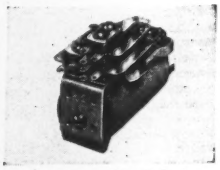


AN-3324-1 D.C.

Series 595 D.C.



Series 610 A.C.—615 D.C.



Series 695 D.C.

WRITE—WIRE—TELETYPE—PHONE NOW!

GUARDIAN ELECTRIC

1638-D W. WALNUT STREET CHICAGO 12, ILLINOIS

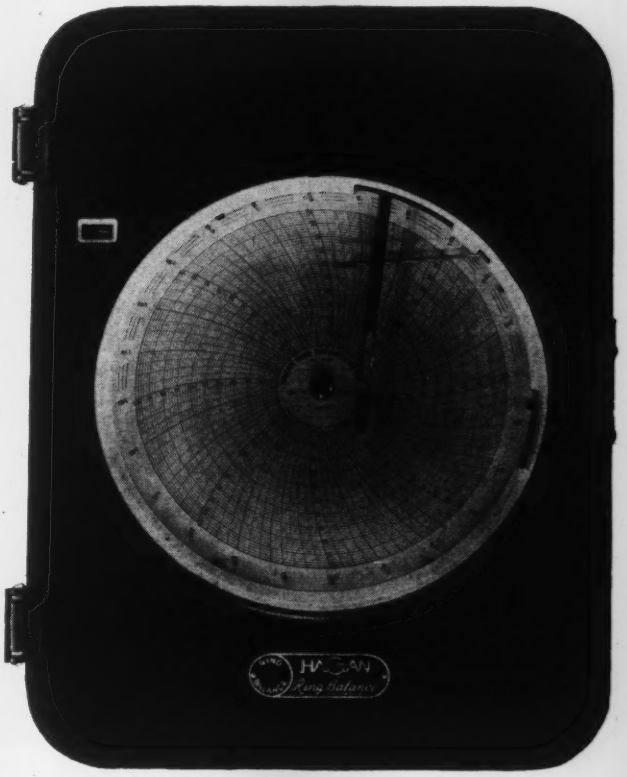
A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY

use dependable HAGAN

Ring Balance Flow Meters

to measure flow of

water–gas–
steam–oil–
air–other fluids



There are many reasons why you get dependable records when you use Hagan Ring Balance Flow Meters.

These include the unique ring torque resistance system which not only makes it possible to meter low flows reliably, but also provides an integral and convenient means for altering the meter capacity to any value over a 3½ to 1 range. Range changing is further simplified by a dead weight method of calibration. Other features include:

- No stuffing boxes
- Adjustable full scale range
- High sensitivity at low flow rates
- Mercury level not critical

Dependable pressure and temperature compensation (either or both) can be furnished with all Hagan Ring Balance Flow Meters.

An economical feature of all Hagan Ring Balance Meters is that maintenance costs are low. For other information on how versatile Hagan Ring Balance Flow Meters will answer your metering problems, clip the coupon, or write.

HAGAN CORPORATION

HAGAN BUILDING

PITTSBURGH 30, PA.

Ring Balance Flow and Pressure Instruments
ThrusTorq Force Measuring Devices
Boiler Combustion Control Systems
Metallurgical Furnace Control Systems

Hagan Corporation I-4
Hagan Building
Pittsburgh 30, Pennsylvania

Please send me further information on Hagan Ring Balance Meters.

I am particularly interested in.....

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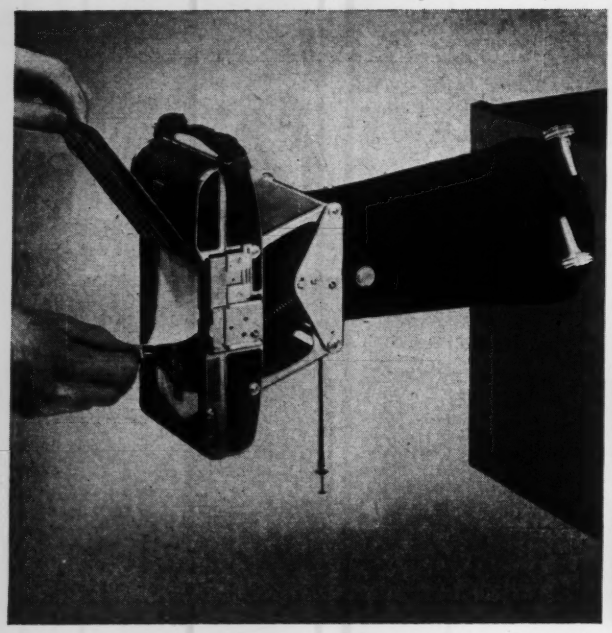
NAME.....

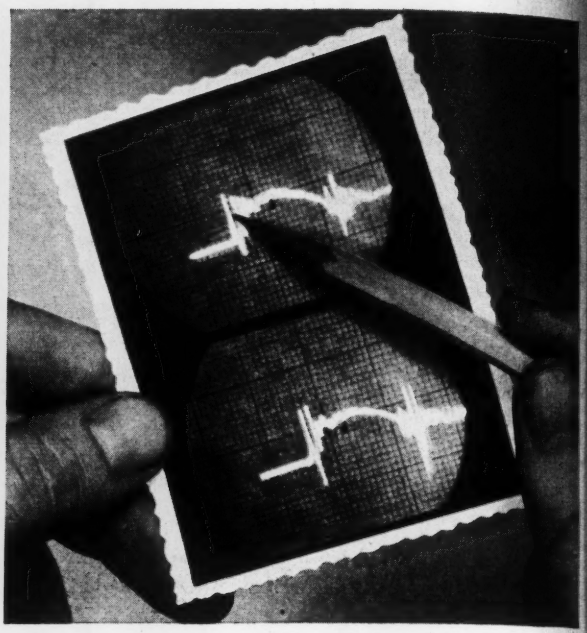
POSITION.....

COMPANY.....

STREET AND NUMBER.....

CITY.....ZONE....STATE.....





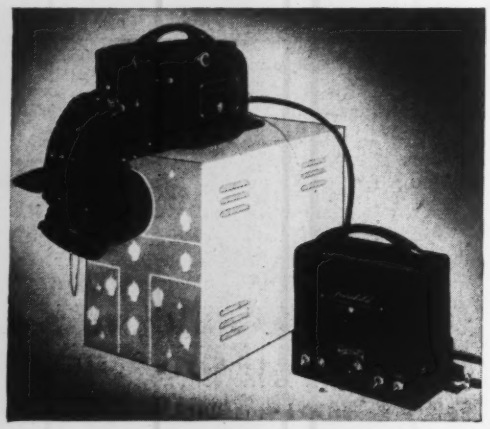
EASY TO TAKE...EASY TO READ

with the Fairchild-Polaroid® Oscilloscope Camera

ELECTRONIC CONTROL GIVES INFINITE SPEED VARIATION

with the Fairchild Oscillo-Record Camera

For both still and continuous-motion recording on 35-mm film or paper, the Fairchild Oscillo-Record Camera is ideal. Continuously variable speed control is provided through electronic regulation. There are no belts or pulleys. Film is sprocket-driven so there is no slippage. Top-of-scope mounting eliminates need for tripod and keeps scope controls easily accessible. There is provision for three film lengths—100, 400, or 1000 feet.



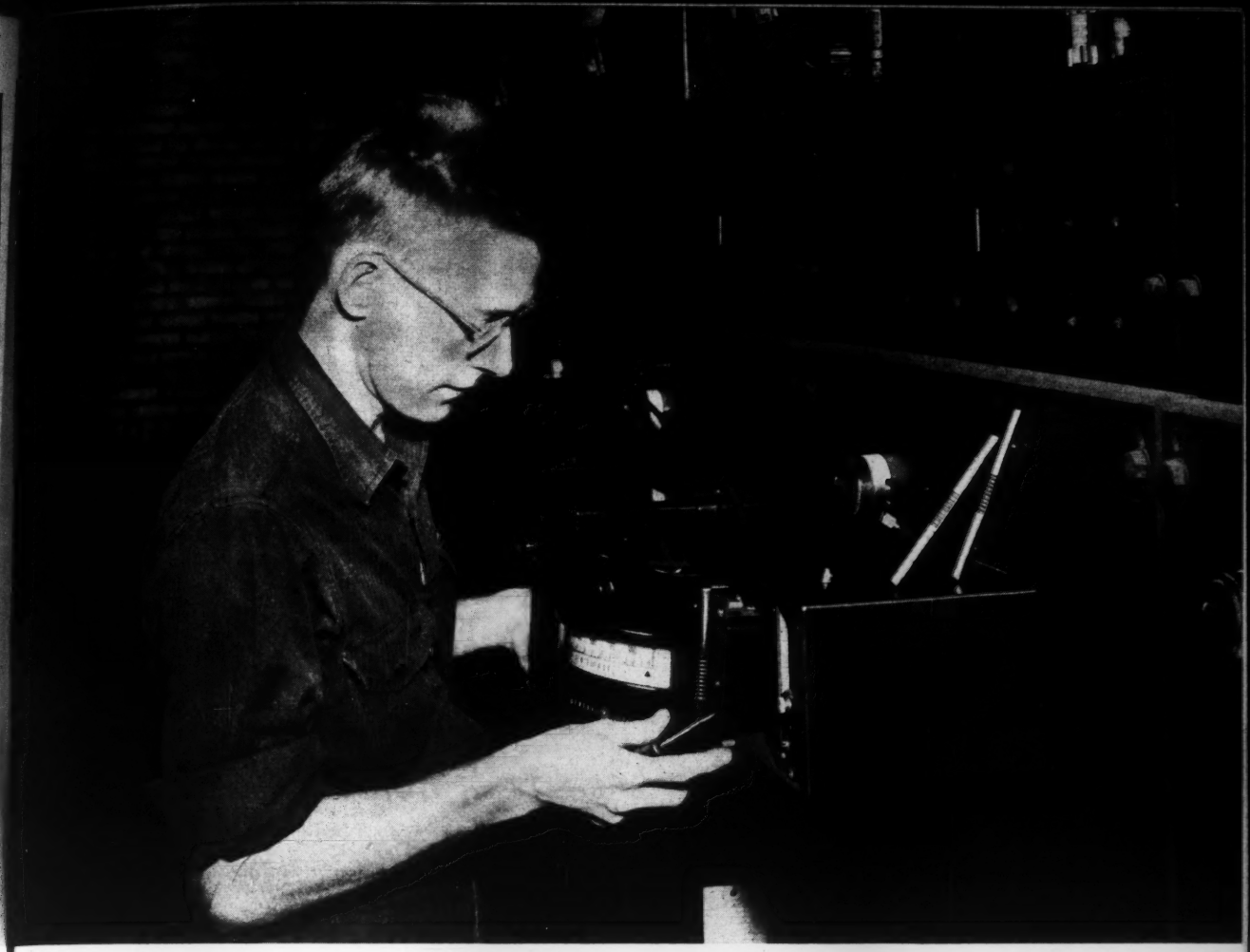
Fairchild's adaptation of the Polaroid-Land camera gives you more than just a fast photographic print of an oscilloscope image. The print is *exactly* half-size for easy measurement of values, especially when a grid is used. And you see the image exactly as it appears on the scope—not reversed. Each 3¼ x 4¼ print records two images.

Moreover, it takes only two minutes (less, if you're fast) to set up the camera, snap the shutter, and pull the tab. Then you wait one minute more and remove the finished print. It's as simple as 1-2-3. No focusing, no special training required.

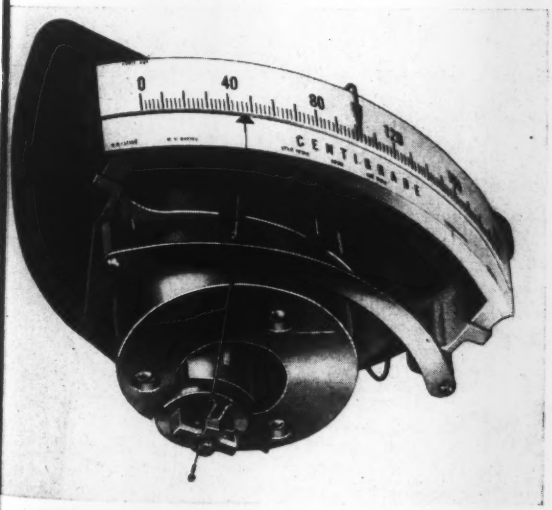
Full information about the Fairchild-Polaroid and Fairchild Oscillo-Record Cameras is available on request. Write today to *Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, New York, Department 120-17F1.*

FAIRCHILD

OSCILLOSCOPE RECORDING CAMERAS



G-E pyrometer equipment resists vibration; gives accurate, uniform temperature control



RUGGED AND ACCURATE. Indicator unit has 3¼ lb. alnico magnet and stationary parts, plus lightweight moving system—a combination that can withstand great stresses.

In the installation shown above, the pyrometer units are giving close temperature control even though subjected to constant vibration, transmitted through frame supports. The atmosphere is filled with coal dust, and has a high ambient temperature. Yet "there has been no trouble in 14 months of operation." So writes a prominent eastern manufacturer.

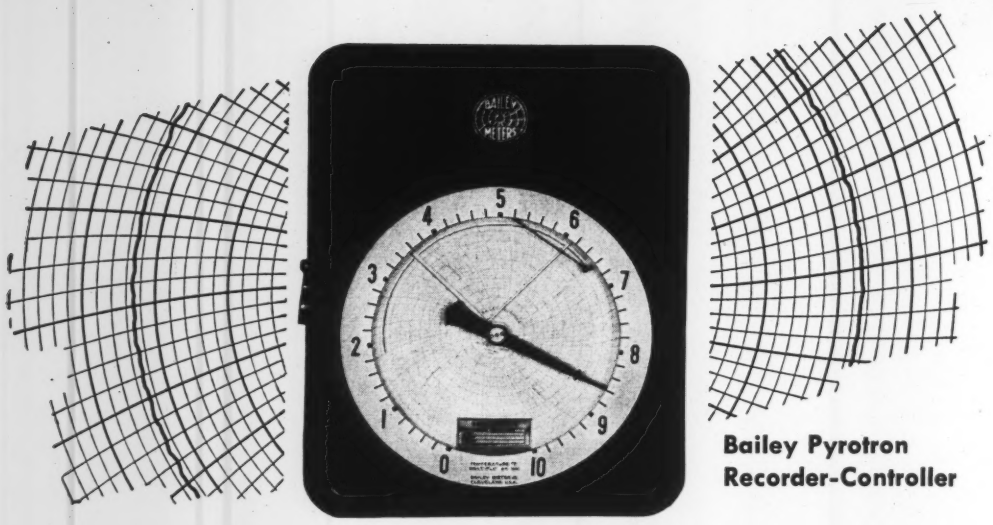
STURDY CONSTRUCTION throughout makes the General Electric Type HP-3 pyrometer equipment rugged and vibration resistant. A 3¼ pound alnico magnet provides high flux density, hence a large air gap for the lightweight (1 gram) moving system. This permits reliable operation under vibration.

ACCURATE INDICATION and uniform temperature control are assured. Calibrated accuracy is within ¾ of 1 per cent of full scale. Automatic cold-junction compensation adjusts for changes in ambient. Normal changes in humidity and voltage have little or no effect on the stability of control.

MORE INFORMATION can be obtained from your G-E representative, or write for Bulletin GEC-713. General Electric also offers a complete line of thermocouples—described in GEC-714. Write Section 602-231, General Electric Company, Schenectady 5, New York.

GENERAL ELECTRIC

602-231



Bailey Pyrotron
Recorder-Controller

Looking for Better Temperature Instruments?

...Then check these features of Pyrotron Electronic Resistance Thermometers...

FUNDAMENTAL ACCURACY

Bailey Pyrotron Resistance Elements are made of highest purity platinum—the material used by the National Bureau of Standards in establishing basic standards for temperatures from −190°C to +660°C.

THREE TYPES OF CONTROL

Pyrotron Controllers may operate: on-off electrical systems by either electronic relays or electric contacts, modulated electronic systems, or air-operated systems. Two temperatures may be recorded on the same chart and controlled by a single instrument.

FACTS PUT INTO USABLE FORM

Bailey Pyrotrons may be arranged to put temperature facts into convenient usable forms. If two or more temperatures are related, they may be recorded as continuous records on the same chart for easy comparison. The average of several temperatures or the difference between two temperatures may be recorded as a single continuous record which may be retransmitted to a distant point or used to actuate a control system.

EASY INSTALLATION

Bailey Pyrotrons do not require careful leveling or protection against vibration. Three ordinary copper wires are all that is needed to connect each temperature sensitive element with the recorder. Power may be taken from any 115 volt 60 cycle circuit.

MINIMUM MAINTENANCE

The absence of galvanometers, batteries and standardizing equipment, together with the use of interchangeable unit assemblies, reduces Pyrotron maintenance to the vanishing point.

ABUNDANT POWER

A separate motor drive for each temperature furnishes abundant power to operate a recording pen, a controller and an alarm switch.

For the full story on this unusual electronic resistance thermometer which is suitable for ranges between −300°F and 1200°F, ask for Bulletin No. 230-C. P-21

BAILEY METER COMPANY

1041 IVANHOE ROAD • • • CLEVELAND 10, OHIO

Controls for Processing

TEMPERATURE
PRESSURE
% OXYGEN
% COMBUSTION
FLOW
LEVEL
DENSITY
RATIO

For *Critical* Applications

Triplett 630-A Has No Counterpart

Accuracy
to 1½%

Readability
with a Mirror-Scale

Adaptability
with ½% resistors

Try it at your distributor's

Triplett

TRIPLETT ELECTRICAL INSTRUMENT CO., BLUFFTON— OHIO

HAMILTON WATCH COMPANY

LABORATORY CHECKS ON MOISTURE IN COMPRESSED AIR

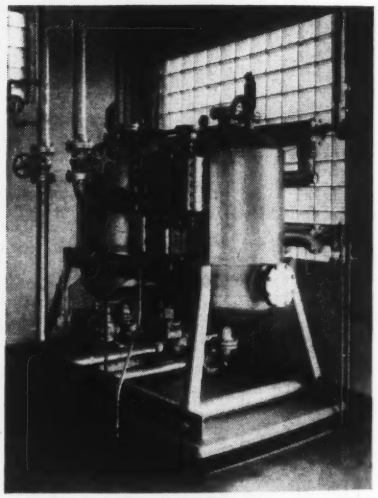
Date	Dep't	Dew Point	Grains/ cu. ft.	Remarks
4/20	Bal. & Flat S.	-50.0° C	.0124	Good
4/20	Works Lab	-50.0° C	.0124	Good
4/23	Bal. & Flat S.	-50.0° C	.0124	Good
4/23	Works	[illegible] C	.0124	Good
4/27	Works Lab	+4.0° C	2.800	Poor NOTE: This situation produced when the new compressor was thrown into use without passing the air through the Lectrodryer.
4/29	Bal. & Flat S.	-54.0° C	.0082	Good
4/29	Works Lab	-54.0° C	.0082	Good
5/3	Oil capsule changed			

A lab man's notebook tells why you need Lectrodryers*

Page after page, the report on moisture conditions was "Good". Then *wham!* It jumped from a hundredth grain per foot of air to 2.8 grains. Howls of protest were heard all through this plant —"What's happened to our air?"

A new compressor had been placed in service, bypassing the old Lectrodryer. A quick switch was made and again the report became "Good".

Lab men's notebooks all over the world are telling this same story: Air is kept free of unwanted moisture by Lectrodryers, assuring dependable functioning of air-operated instruments. For help in determining what Lectrodryers will do for you, write Pittsburgh Lectrodryer Corporation, 330 32nd Street Pittsburgh 30, Pennslyvania.



The new Type BY automatic Lectrodryer gives you DRY air at minimum investment

In England: Birlec, Limited, Tyburn Road, Erdington, Birmingham.
In Australia: Birlec, Limited, 51 Parramatta Road, Glebe, Sydney.
In France: Stein et Roubaix, 24 Rue Erlanger, Paris XVI.
In Belgium: S. A. Belge Stein et Roubaix, 320 Rue du Moulin, Brassoux-Liege.

LECTRODRYERS DRY WITH ACTIVATED ALUMINAS

LECTRODRYER

* REGISTERED TRADEMARK U. S. PAT. OFF.

CHECK THESE 3 WAYS YOU CAN SAVE WITH THIS MULTI-PURPOSE INSTRUMENT

Here is the most sensible idea you've ever seen in a recorder or controller—an instrument you can change as your instrument needs change, that you can add to, subtract from, or whose functions you can increase or decrease at little or no expense.

✓ **Save money when you add new functions by adding only those new assemblies needed.**

✓ **Save time-delays by making changes on the job site without returning to factory.**

✓ **Save money on inventory. Parts are interchangeable, fit all Gotham Convertible recorders. You can service a whole group with a minimum stock of basic elements.**

What you can do with the Gotham Convertible

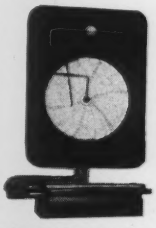
Depending on the chart size of the recorder (6″, 9″ or 12″) you can have a 1-2-3 or 4 pen recorder with 14 pressure, temperature and time operation combinations or a recorder-controller with 38 possible pressure, temperature, and time combinations.

SELF-CONTAINED PORTABLE RECORDER

A portable recorder which has a carrying handle, legs and retaining holder for capillary and bulb. Built from Gotham standard elements, interchangeable with other Gotham instruments. 6", 9" and 12" chart sizes. Mercury, Vapor or Pressure Activated. Spring or electric chart drive. See Catalog 400.

RECORDING PSYCHROMETER

Incorporates the same highly accurate and responsive thermal systems and contains all other Gotham standard convertible features. Wet and dry bulb type. Motor-driven suction fan. 12" chart size. Catalog 400.



RECORDING HYGROMETER

A 2-pen recorder of the wet and dry bulb type. Mercury or Vapor Actuated. 9" and 12" chart sizes. Available with variety of wet and dry bulb assemblies depending on application. Catalog 400.

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Keep everything under control with Gotham

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Division of American Machine and Metals, Inc.
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Please send me a copy of your

- ☐ Catalog 100—Industrial Thermometers
- ☐ Catalog 200—Dial Type Thermometers
- ☐ Catalog 400—Recorders, Psychrometers, Hygrometers
- ☐ Catalog 500—Controllers
- ☐ Have your representative call. No obligation.

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MAGNETIC COUPLING

A BASIC ADVANCE IN INSTRUMENTATION
...eliminates the stuffing box

Particularly suited for flow measurement or level determinations

The patented, separation-proof MAGNABOND Magnetic Couplings are simple, safe, positive, and precise. They utilize a unique system of permanent magnets to pick up the float position of a primary element eliminating the need for stuffing boxes or packing glands.

After years of highly successful use with FLOWRATOR variable-area flow measurement meters, the MAGNABOND coupling's usefulness is being extended to LEVELIMETER liquid level measurement instruments, V/A Cell Kinetic Manometer flow units, and Mercury Manometer flow meters.

For more information about the MAGNABOND coupling, its applications and possibilities, ask for Catalog 75 describing F&P Levelimeters; Catalog 37 on Mercury Manometer Flow Meters; Catalog 42 on V/A Cell Flow Meter units; Catalog 50, describing MAGNABOND Transmission and Exhibiting and Controlling Instruments for use with FLOWRATOR Meters.

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MOLTEN SOLIDS
INFLAMMABLES
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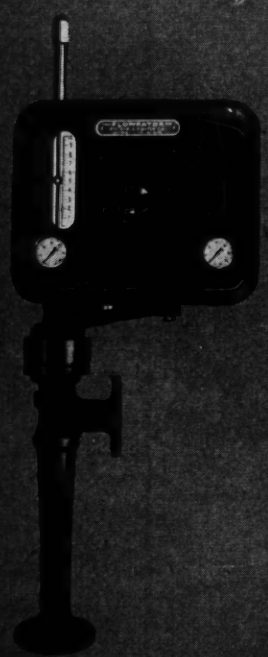
HATBORO, PENNSYLVANIA, U.S.A.
SALES ENGINEERING OFFICES THROUGHOUT THE WORLD

SOME MAGNABOND SYSTEMS



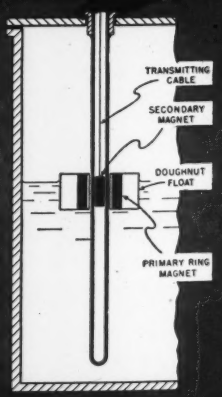
VARIABLE-AREA FLOW MEASUREMENT
FLOWRATOR flow meter

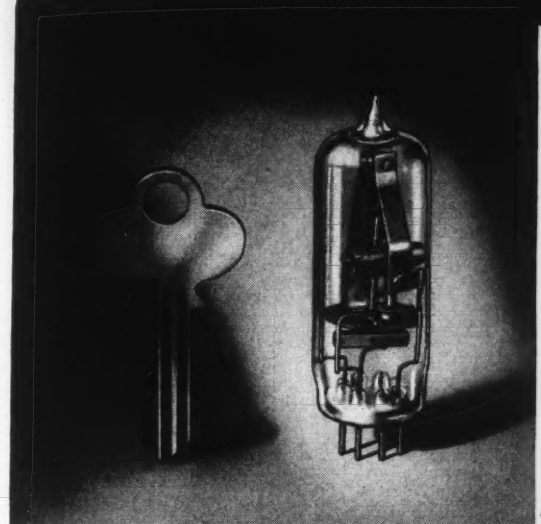
LEVEL MEASUREMENT
LEVELIMETER, Cable & Drum, liquid level meter

DIFFERENTIAL PRESSURE MEASUREMENT

F&P Mercury Manometer flow meter

V/A Cell Kinetic Manometer flow meter





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FOR . . .

Cathode Protection
Gyro Erection
Motor Starting
Integration
Holdovers
Overload Protection
Current Interruptions (Flashers)
Cycling Durations
Emergency Circuit Switchovers

Announcing . . . a NEW Miniature by EDISON

EDISON announces its new Model 207 Miniature Thermal Relay — designed to meet the need for a space-saving time-delay relay.

Into the design and development of this sealed-in-glass miniature, EDISON has applied the experience of over 20 years in the thermal engineering field and has built into it many of the quality features of the widely-used EDISON Model 501 Thermal Relay. In numerous applications the two relays have similar operating characteristics.

Pilot production started in December 1951. For free bulletin, just clip coupon and mail.

SPECIFICATIONS • MODEL 207

Sealed-in-glass
Arc quenching atmosphere
Precision timing — Final adjustment made *after* sealing by patented feature
Weight: ½ oz. (approx.)
Diameter: ¾" (approx.)
Height: 2¼" maximum (seated)

Standard Heater Voltages: 115v, 27.5v, 6.3v
Contact Ratings: 2.5 amps @ 125v ac., 1.0 amp @ 125v dc.
Ambient Compensation: −60 to +85°C
Nominal Heater Input: 2 watts

Mounting: Miniature Button 7-pin
Range of Delay Periods: 5 secs. to 120 secs.

OTHER INSTRUMENT DIVISION PRODUCTS

Sealed Thermostats
Sensitive Relays
Temperature Monitors
Electrical Resistance Bulbs

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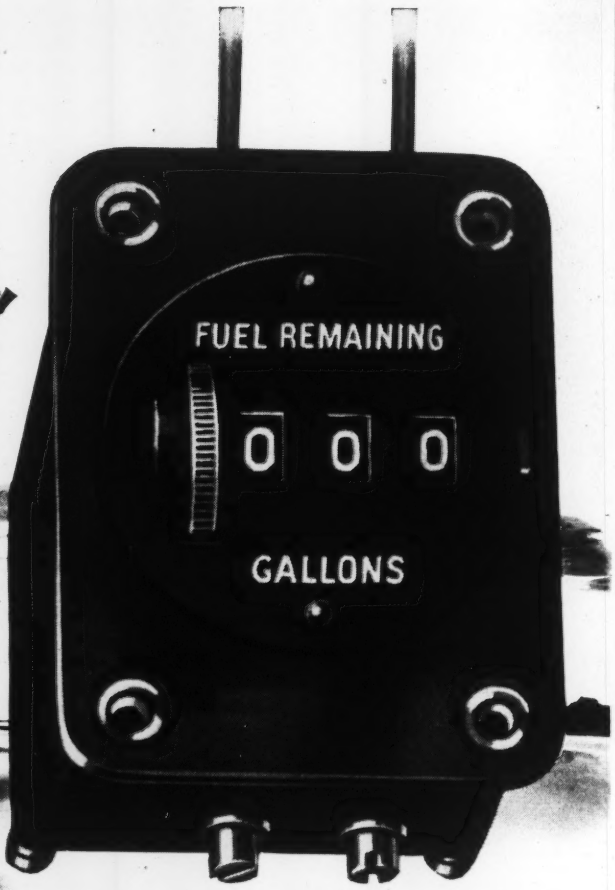
Thomas A Edison
INCORPORATED
Instrument Division • West Orange, N. J.

To: Instrument Division, THOMAS A. EDISON, INC.
63 Lakeside Avenue, West Orange, New Jersey

We may have an application for your Miniature Thermal Relay to_____

Please send bulletin I5 to: _____
Name and title_____
Company_____
Address_____

It Subtracts... so Pilots can "add up the score"



Added Evidence that—

Everyone Can Count on

VEEDER-ROOT

Yes, jet pilots count on this interesting instrument to tell them how much fuel is left . . . when they'd better "hit for home." And in the same way, it counts rounds of ammunition remaining in the plane's machine guns, the number of film-exposures remaining in aerial cameras, etc., etc. So you can see how one type of Veeder-Root Counter can come up with many answers to many problems. And within the literally *infinite* scope of the counting process, there may well be some badly needed answers we can work out for *you* . . . if your work is badly needed for defense. Write.

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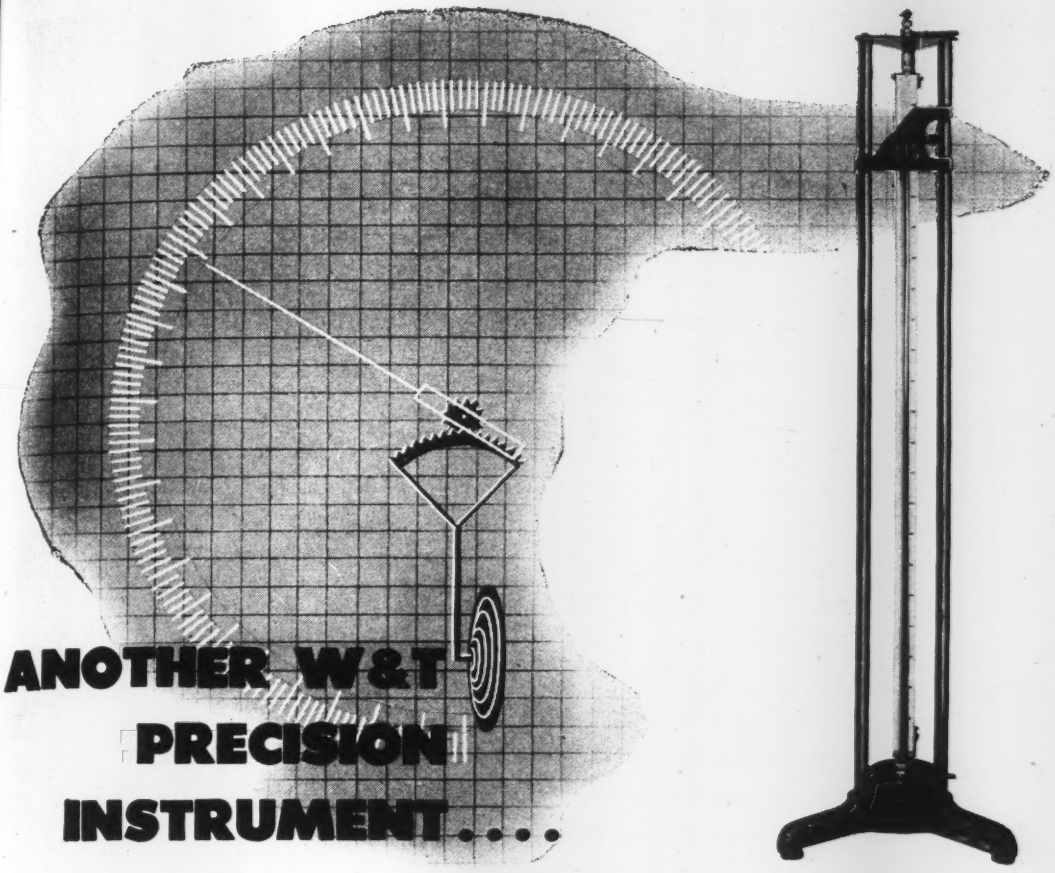

ANOTHER W&T PRECISION INSTRUMENT....

The W & T Precision Mercurial Manometer

The W&T Precision Mercurial Manometer couples maximum precision with ease in handling. These two features have made it a leading instrument in modern research and manufacture for such uses as measuring sample pressures in infrared spectroscopy and calibrating aircraft altimeters. Because of its flexibility and accuracy, the Manometer can be used for almost any type of pressure measuring problem in the range of two atmospheres.

Such characteristics are only part of the picture. Take a look at these additional features:

1. Float type indicator eliminates difficulty in reading meniscus.
2. Adjusting knob provides for temperature compensation over a range of 30° C.
3. Precision bore manometer tube provides accuracy with interchangeability.
4. Fixed cistern type manometer requires only one reading.
5. Mercury sealed valve permits evacuating the tube simply and easily at the point of use.
6. Flexible design permits measurement of absolute pressure, gauge pressure, differential pressure, and vacuum.

For more details, write today for free technical bulletin TP-29-A.

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PRODUCTS, INC.
ELECTRICAL MECHANISMS AND PRECISION INSTRUMENTS
Belleville 9, New Jersey • Represented in Principal Cities

This heat-treating record ... is NEWS

The above chart shows a record of surface carbon control during four types of heat-treating processes. During three of these operations carbon is added; during the fourth, it is accurately maintained.

This record, provided by the familiar Micromax Recorder modified for this purpose, is an exclusive feature of the Microcarb method of carbon control as applied to the Homocarb furnace. There is no other way of getting even one of these records, much less all four.

Ninety-nine out of a hundred metallurgists and heat-treaters will find this record is new... something they have never seen before. It tells them exactly what's going on...gives the heat-treater time enough to modify the process or take whatever other action is desirable. It's the NEW way to reduce rejects.

The significance of this new development will, of course, depend upon the plant setup, and must be assessed individually by the metallurgist or heat-treater concerned. However, initial users of Homocarb with Microcarb control are enthusiastic.

One such firm found the results so important to their customers that they featured the story in their own advertising. As more and more manufacturers become familiar with the advantages of Homocarb plus Microcarb, this equipment will soon be more generally known to men who look for the modern way to carburize.

Let us send you further facts about this new development. We may be contacted at our nearest office, or 4955 Stenton Ave., Phila. 44, Penna.

LEEDS & NORTHRUP CO.

INSTRUMENTS • AUTOMATIC CONTROLS • FURNACES

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Editorial Comment

The IRE Show

As usual, *Instruments* had a booth at the IRE Show, not only to exhibit your magazine, but also to keep the instrumentation field in the attention of the radio industry and engineers.

The technical papers presented at the IRE Show covered the fields of (1) communications—color television, antennas, microwaves, radio, and wave propagation, (2) high-frequency instrumentation and electronic measurements, and (3) circuits and circuit theory—filter theory, transient response of amplifiers, etc. The symposiums on transistors and computers were very popular. Of particular interest to instrument men were exhibits of computers (digital and analog) and radioactivity instruments.

Computers

The rapid growth and the new developments in the computer field are laying the groundwork for a minor revolution in industry—one which *Instruments* will report carefully to its readers. The computers now being developed may soon be an integral part of the plant instrument system. The output of all measuring instruments—flow, temperature, pressure, density, composition, etc.—not only will be recorded and controlled by conventional instruments, but the data also will be transmitted to the computers. These new instruments will automatically integrate, correct for all variables, and perform all calculations necessary for plant operation and accounting. Their output will be the "finished product" desired by the plant and accounting engineer—efficiency data, cost data, etc. The output will be printed on cards, suitable at once for direct use.

There were several exhibitions of digital and analog computers at the show. The major emphasis at present is on rapid extraction of information from the computers. One new device of significance in this field is the "flying typewriter," described on the following page. Another output device is the "charactron," described on page 488 of this issue. (See also New Literature item U-342.)

Much development work is being done also on memory storage systems for computers.

Measuring Instruments

As is to be expected, most of the instruments exhibited at the IRE show were test instruments for electronics research and development. However, instruments were shown for the measurement of acceleration, vibration, frequency, pressure, vacuum, and radioactivity. The Wright Engineering Co. displayed its new "Digitran" pickup, which is described on page 424 of this issue (see New Instrument item 411).

Mention should be made also of the "Increductor" (see New Literature item U-368). This device, which works on the well-known principle of changing the reactance of an inductor by changing the core permeability, may have uses as a magnetic amplifier, but at frequencies higher than those possible with saturating-type magnetic amplifiers.

In addition to the "Increductor" there were several exhibits of the new and important solid-state amplifiers—transistors and magnetic amplifiers. A feature article on these new devices, which are of particular importance to instrument men, will appear in the next issue of *Instruments*. (See Chap. 9 of the INSTRUMENT ELECTRONICS serial in May.)

Control

The controlling devices exhibited were primarily electromechanical servomechanisms, including motors, differentials, and other servo components.

An Opportunity

Dr. Axel Peterson of Mellon Institute, chairman of the ISA National Committee for Analysis Instrumentation, addressed the graduate class in Process Instrumentation at the University of Pittsburgh and made some comments that are worth repeating to a larger audience. He emphasized that the chemical engineer who enters a plant via its Instrument Department has several advantages over the engineer who enters via the Engineering Department. First, the former is one of a smaller group—usually, he is one among dozens, the latter may be one among thousands. Second, the instrument man will learn all phases of plant operation—and usually in a short time. The instrument man must know not only instruments, but also the process. As instruments are now a vital part of each phase of the process, the instrument engineer soon learns the process details of every part of the plant. Obviously this is excellent preparation for plant managers and executives.

In contrast, the average member of the Chemical Engineering Department is assigned to one part of the plant or process. Although he can rise to an executive position in that department, he is in competition with a much larger group of men.

Similarly in the iron, steel, and byproducts mill, the instrument man works on blast furnaces, open hearths, rolling mills, boiler houses, coking ovens, tar plants, distillation towers, and batching tanks. In no other department of the plant can a man acquire more working knowledge of the plant than in its instrument department.

Thus the instrument department of any industrial plant may well represent one of the shortest paths to the top for men entering industry.

New Labor Pool Tapped

The Electro Tec Corporation has selected Ormond Beach, Fla., as the location for an experimental laboratory, to be staffed by engineers and technicians who have retired to that area. This plan is worthy of mention for several reasons. First, it is well known that retired personnel often have wonderful backgrounds of both experience and training. Second, inflationary trends have made it necessary for many retired people to seek added income—indeed, many who retire find that excessive leisure is no pleasure. The Electro Tec Corp. deserves commendation for this healthy development. Their manufacturing operation will remain in New Jersey.

Instrumentation in Research

In the past, the directors of research laboratories expected each research man to be a skilled instrument man. Indeed, they often expected him to design his own instruments. Fortunately, however, laboratory management is becoming aware that the research laboratory requires full-time instrument men to provide the research men with the proper tools for their labor—that is, if inefficiency and labor duplication are to be reduced. The trend is obvious; the following research laboratories recently have organized instrument sections: Mellon Institute of Industrial Research; Research Laboratory, Pittsburgh Plate Glass Co.; Battelle Memorial Institute; Southwestern Research Institute; and Research Laboratory, Johns-Manville Co.

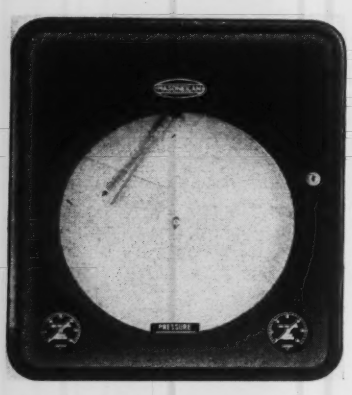
The Month's NEW INSTRUMENTS

In this department we report each month new devices for measurement, inspection, testing, computing, metering and automatic control—in the form of concise technical descriptions.

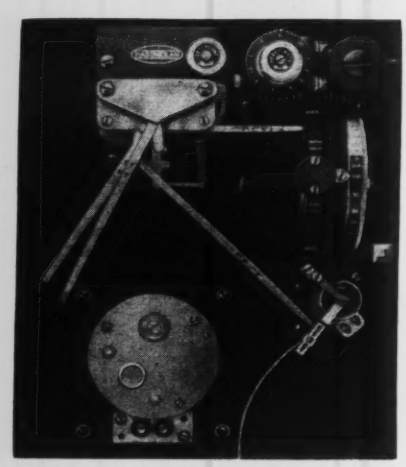
FOR FURTHER INFORMATION USE THE POSTAGE-FREE ORDER CARD ON PAGE 517

Automatic Controllers

New "60000 Series" air-operated automatic controllers for pressure, temperature, level and flow-rate are available in recording and indicating types, with principal modes of control as follows: (1) Proportional, direct or



reverse, with 0 to 200 percent proportional band; (2) proportional-and-reset, with 0.02 to 6 repeats-per-minute reset rate; (3) on-off; (4) differential gap, with range of 0 to 100 percent. Supplementary types available: (*a*) pneumatic-set, with range 0 to 100 per-

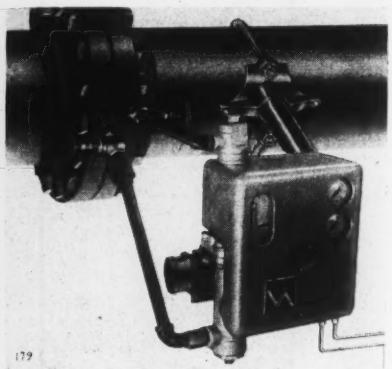


cent; (*b*) time cycle; (*c*) differential: indicating or recording both independent and dependent variable; (*d*) manual control unit on sub-panel with 4-position (manual-automatic-test-service) non-bumping transfer switch. All types embody new design and construction features.—*Mason-Neilan Regulator Co.*, 1190 *Adams St., Boston* 24, *Mass.*

Mention No. 401 when filling out card.

By-pass-flow Orifice Meter

New "V/A Cell" utilizes "shunt" principle of metering. Instead of measuring static-pressure differential across orifice, new unit meters a continuous bypass stream around that orifice. Principal parts are: a variable-area meter whose float position inside a tapered tube changes with flow; a



balanced follower arm, magnetically linked to float; and a pneumatic unit for transmitting flow-rate measurement to remote instruments. Claimed advantages: (1) constant flow continuously purges lead lines, (2) linear relation exists between metered flow and main flow past orifice, avoiding square-root relation, (3) enormous flexibility, (4) adaptability to pneumatic connection to remote points, (5) ability to meter all types of corrosive and non-corrosive fluids.—*Fischer & Porter Co., Hatboro, Penna.*

Mention No. 402 when filling out card.

Vacuum-tube Voltmeter

New "WV-87A Master VoltOhmyst" reads peak-to-peak values of complex waveforms and rms. values of sine waves; also d-c. voltage, resistance, and direct current. Has d-c. probe, ohms probe, negative current cable, positive current cable, and ground cable.—*RCA Tube Dep't, Radio Corp. of America, Harrison, N. J.*

Mention No. 403 when filling out card.

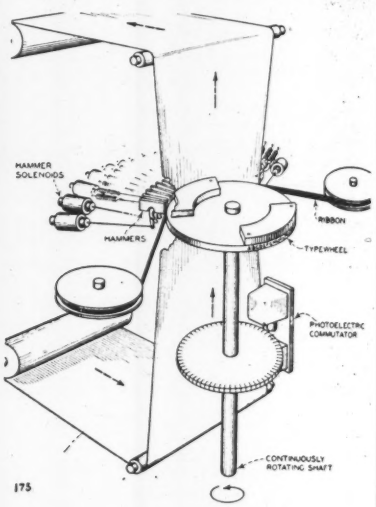
Camera Back

New Polaroid-Land back permits making finished shots in one minute using a 5x7 or 8x10 commercial view camera with wide range of interchangeable lenses, normal wide angle, telephoto, etc.—*Burke & James Inc.*, 321 *So. Wabash Ave., Chicago, Ill.*

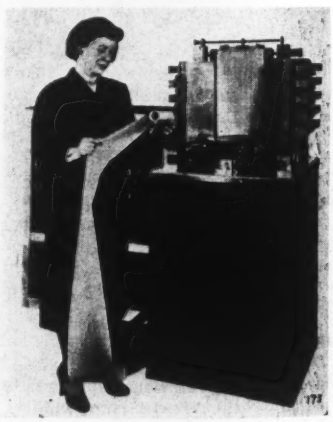
Mention No. 404 when filling out card.

Millisecond Typewriter

New "Flying Typewriter" prints data at rate of 24,000 characters per minute (2.5 milliseconds per character). Total of 47 characters comprising alphabet, numerals, and symbols are on typewheel rotating at 300 rpm. Coded pulse signal



operates hammer solenoids that strike paper against typeface. A line at a time is printed using ordinary paper, standard typewriter ribbon, and hard-face type. Electronic series-parallel storage unit accepts information in coded pulse form from an external source such as a computer, magnetic tape, punched cards, etc. Eighty channels corresponding to eighty characters per line may be series or parallel fed to input requirements. Information is alternately stored and extracted in these channels, completing this cycle once for each line printed. Photoelectric pulse generator on shaft



of print wheel processes characters out of electronic storage unit, which can be used as part of computer to perform addition, subtraction, division, multiplication, and shift information being printed to any selected columns. Numerous applications are anticipated in mass filing and data handling.—*Potter Instrument Co., Inc. Great Neck, N. Y.*

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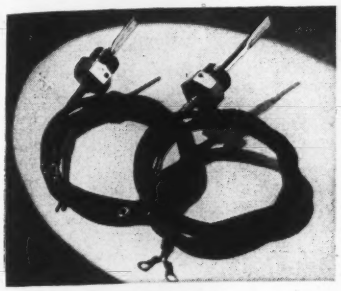
Resistance Thermometers

New "Type 21" resistance-thermometer primary-element assemblies are available in several ranges between 0-100 and 0-1000 deg. C. Element is



enclosed in spade-shaped tip of stainless-steel or Inconel tube: flat shape reduces thermometric lag to less than one second. Each unit is accompanied by a calibration certificate. Guaranteed accuracy is 1 percent full-scale.–*Trans-Sonics, Inc., Bedford Airport, Bedford, Mass.*

Mention No. 406 when filling out card.

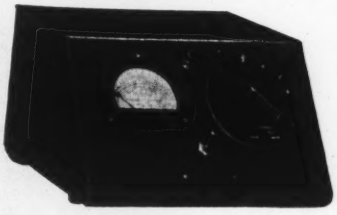
Precision Resistance Thermometers

New "Fuse-Din Armored Precision Thermometer" is not as brittle as conventional platinum-and-glass thermometers. Over-all length is 14¼ in.; stainless-steel protection tube is ¼ in. o.d. Head is 1 in. dia. and 1¼ inches long; four terminals are fused into disk of borosilicate glass. "Type PBM," for temperatures up to 300 C., is cast in lead and has resistance unit of tungsten, fused into pyrex; "Type PPC," for measurements to 1500 C., is platinum, fused into a ceramic matrix, with internal leads of platinum.—*Weiller Instruments Corp., 95 Broad St., New York 4, N. Y.*

Mention No. 407 when filling out card.

Temperature Controllers

New line of "Temcometer" automatic temperature controllers embody multiple-contact mechanical-type relay system in place of single-contactor or



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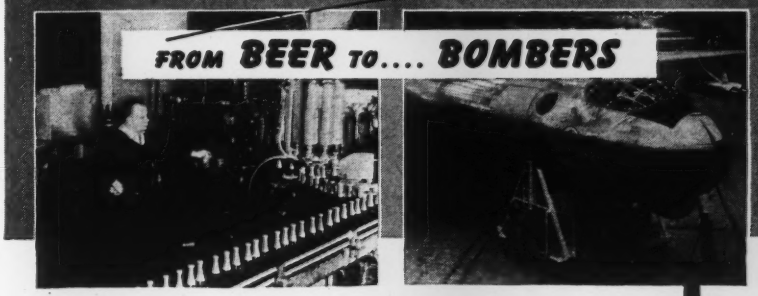

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Century

RECORDING GALVANOMETERS

The Century Model 210 Galvanometer has been designed and tested for the utmost in performance under any conditions. The unique small tubular type construction permits their installation in practically any type or make of photographic recording oscillographs. These galvanometers are offered at low cost over a wide range of frequencies and sensitivities to satisfy most recording requirements. For additional information, write for our Catalog No. CGC 206.

Manufactured under Century Pat. 2439576, also licensed by Kannestine Laboratories Patent 2149442.

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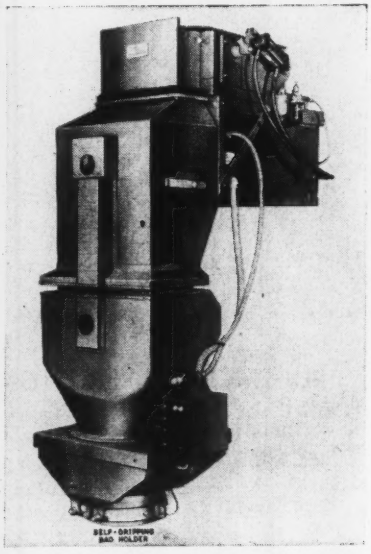
NEW INSTRUMENTS

mercury-type relays formerly used. Fused circuit divides load current between contacts to prevent damage to furnace or oven and its contents. Thermostatic control unit which regulates "on" and "off" cycles has improved stability and longer life.—*Thermo Electric Mfg. Co., 496 Huff St., Dubuque, Iowa.*

Mention No. 408 when filling out card.

Filling Scale

New "Model 400 N" Filling Scale permits bulk materials to be automatically net-weighed and bagged at speeds up to 12 per minute for 50-lb. bags and 10 per minute for 100-lb. bags. Guaranteed accuracy, 0.1 lb. for any weight from 25 to 200 lbs. Mechanical parts



and electrical conrtols are enclosed in dust-proof housings. Push-button dumping and bag-releasing system, exterior dials for pre-setting weights and tolerances and timer for adjusting load frequency speeds are standard equipment. Duplex units, with double bagging speeds of single units, are available.—*Thayer Scale & Engineering Corp., East Water St., Rockland, Mass.*

Mention No. 409 when filling out card.

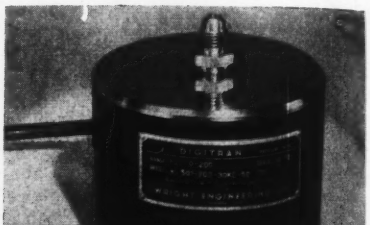
Temperature-monitoring Desk

New process-operator's desk has "ElectroniK" indicating potentiometer and either key-switch banks or push-button assemblies, making it possible to obtain 72 or 96 temperature readings in seconds. Desk with key switches has maximum of 72 indicated thermocouple points. Desk with push-buttons (non-locking only) has maximum of 96 thermocouple points, either indicated only or normally-recorded optionally-indicated.—*Brown Instruments Div., Minneapolis-Honeywell Regulator Co., Wayne & Windrim Aves., Phila. 44, Penna.*

Mention No. 410 when filling out card.

Pressure and Displacement Pickup

New "Digitran" provides output frequency proportional to movement of a diaphragm, which can be actuated by pressure, force, acceleration, and displacement. Natural frequency of vibrating element is preset in manufacture between 2 and 10 kc. Variation of frequency for full-scale range can be from ±2 to 50 percent of center



frequency. Resolution can be as great as 1 part in 30,000. Frequency output can be read and recorded by use of "Potter" counter equipment which converts frequency to digital numbers. "Model 500," for use where space and weight limitations are at a minimum, has ranges from 0 to 5 psi. absolute (0 to 10 microns absolute) to 0 to 10,000 psia. "Model 501" has temperature-controlled container and same ranges. "Model 502" has temperature control and two "Digitran" elements; ouputs are heterodyned to zero frequency to make a direct-indicating instrument.—*Wright Engineering Co., Pasadena 1, Calif.*

Mention No. 411 when filling out card.

Electrometer

New "Model 145 Electrometer" is a-c. operated; features direct indication of d-c. potentials from 0 to 150 mv. (full-scale deflection of 30 mv. is available). Input terminals available inside a shielded compartment on front

panel or on remote probe. Provision is made for connection to a strip-chart recorder. Dimensions: 14 x 15 x 9 in.—*Special Instruments Laboratory, Inc., 1003 Highland Ave., Knoxville, Tenn.*

Mention No. 412 when filling out card.

pH Electrometer

New "Model 20 Compax" portable pH electrometer combines precision of linear potentiometer with simplicity of single-dial operation. Features include:

"Flashing Signal" which establishes reading point with pin-point precision; protection against measurements errors due to depleted batteries, amplifier drift, or accidental misadjustment of controls; electrode system automatically brought to operating position when instrument cover is opened and returned to storage within case when cover is closed. All operations of standardization and measurement accomplished with single calibrated dial.—*Coleman Instruments, Inc.*, 318 *Madison St., Maywood, Ill.*

Mention No. 413 when filling out card.

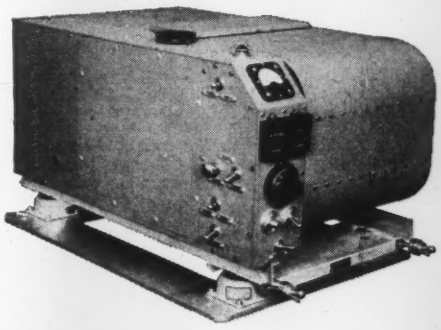
Electrometer

New "Model 200A" electrometer has two scale ranges: 0-2 and 0-8 volts; also separate zero-center scale. Two new voltage dividers—"Model 2002"

Century INDUSTRIAL

RECORDING OSCILLOGRAPH

FOR VIBRATION, TEMPERATURE, STRESS, STRAIN ANALYSIS



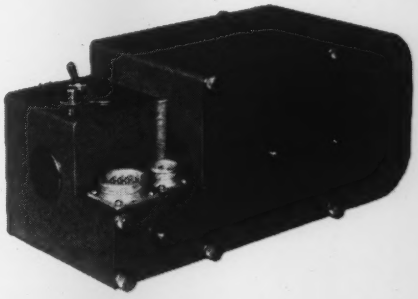
MODEL 408 OSCILLOGRAPH

The Century Model 408 recording oscillograph was designed expressly for airborne and mobile operation. As with all Century products, this oscillograph incorporates the utmost in design and workmanship, along with improved features, yet it remains simple in its operation and maintenance.

FEATURES:

- Size: 20" long, 12½" wide, 8⅞" high.
- Weight: 60 pounds.
- Number of Recording Channels: 6 to 50.
- Detachable daylight loading magazine accommodating a roll of paper or film 8" x 200'.
- Friction roller type paper drive by governor controlled electric motor with separate motor for takeup drive.
- Paper speeds continuously and instantly variable without changing gears or sprockets.
- Separate optical system for viewing before or during recording.
- Glow tube timing system photographing .01 second and .1 second lines. .01 second lines instantly removable by toggle switch for slower speeds.
- Data numbering at beginning of record.
- Footage indicator showing amount of paper remaining in magazine.
- Automatic record length control.
- Trace identification.
- Remote control unit.

MODEL 409 OSCILLOGRAPH



The Century Model 409 oscillograph has been designed for recording data where space and weight requirements are limited. This oscillograph has been tested to record faithfully while subjected to accelerations up to 20 G's.

FEATURES:

- Size: 5" x 5" x 11".
- Weight: 11 pounds.
- Cast Aluminum case.
- Paper speeds variable ½" to 12" per second.
- Detachable daylight loading magazine with a capacity of 3⅝" x 50' paper or film.
- 2 to 12 individual channels.
- Trace identification.
- Trace viewing.

For Complete Information Write 1340 North Utica

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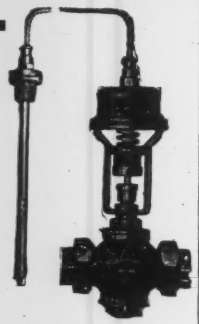
TEMPERATURE REGULATORS

ATLAS

WHAT DO THEY DO ?



1—ATLAS Temperature Regulators continually maintain the desired temperature of steam heated air, water, oils, or other liquids by automatically adjusting the steam supply for such heating.

2—On dry rooms they control the temperature by operating dampers or diaphragm valves on the steam supply lines.

3—On hot water tanks they control the temperature of the water by operating diaphragm valves on the steam supply lines to the heating coils.

4—On hot water instantaneous heaters or generators they control the temperature of the water within a few degrees variation by operating, through a relay, diaphragm steam valves of any size almost instantaneously.

5—On cookers, vats, scalding or other open tanks they control the temperature by operating diaphragm valves on the steam supply lines.

6—They can be adjusted to operate at any desired temperature up to 300 deg. Fahr., and accurately hold their temperature adjustment regardless of the variation in pressure or demand for steam.

7—Each regulator will operate one or more control valves of any size from ½" to 8".

8—The diaphragm steam control valves are made suitable for any pressure from atmospheric to 250 lb. for saturated or superheated steam and are opened wide or shut off tight on a temperature variation of less than 2 degrees.

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☐ Please send Bulletin 7A on ATLAS Self-Contained Temperature Regulators. ☐ Send Bulletin 6A, Hydraulically and Pneumatically Operated. Also, send data on the ATLAS products checked below.

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NEW INSTRUMENTS

with a 100:1 ratio, and "Model 2003" with 10:1 ratio make five ranges available: 0-2, 8, 20, 80 and 200. Quick conversion to a micromicroammeter is accomplished with shunts. Addition of "Model 2004 Test Voltage Supply" results in a megohmmeter.—*Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio.*

Mention No. 414 when filling out card.

CO_2 Indicator

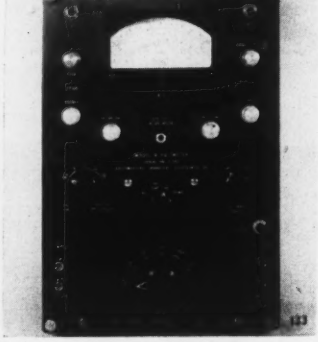
New portable carbon-dioxide indicator for combustion processes is self-contained, including a sample pump and filter. A change in reading is 90

percent completed within twenty seconds. Thermal-conductivity-type analysis is used. Analyzing cell is protected from corrosion; no driers are required. Standard range is 0-20 percent; special low-range instrument can be scaled as low as 0-5 percent. Instruments can be calibrated for any combination of gases where thermal-conductivity analysis applies.—*Robert D. Richardson, R. 3, Box 345, Michigan City, Ind.*

Mention No. 415 when filling out card.

Versatile VTVM

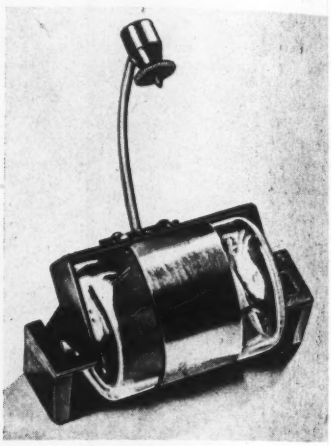
New "Model R Voltmeter" measures a-c. and d-c. voltages and ohms. Unique feature is distended voltage scale, accomplished by bucking out 99 percent of measured voltage and distending the remaining 1 percent over full-scale range, permitting accurate readings of millivoltages at any level. Full-scale ranges (a-c. and d-c.) are: millivolts—1 to 1000 in 7 ranges; volts—1 to 1000 in 7 ranges; ohms—times 1 to times 10^6 in 7 ranges. Other features: (1) distended ohms range, (2) d-c. amplifier with frequency range of 0 to 100 kc. and 1-ma. output, and (3) self-contained standard cell for calibration.—*Southwestern Industrial Electronics, 2831 Post Oak Road, Houston 19, Texas.*



Mention No. 416 when filling out card.

Instrument Pens

New industrial instrument pens eliminate flooding and reduce paper plugging. Pens have removable tips and new reservoir construction which elim-

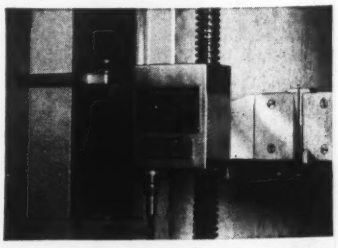


inates flooding because effective ink level is always below writing tip. Pen operates with decreased pressure on instrument chart; cleaning is made easy by simple disassembly, and new design fits on standard pen carriages. Tip is made of platinum alloy.—*Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Wayne & Windrim Ave., Phila. 44, Penna.*

Mention No. 417 when filling out card.

Strain Instruments

New line of "C-Type" low magnification strain instruments comprises: "C-1" with 3 magnifications of 10, 20, and 40; "C-2" with 1, 2, and 4; "C-3"



with 2.5, 5, and 10. When used with "S-Type" extensometer, complete stress-strain curves can be autographed without stopping tests. Signals are transmitted by "Atcotran" differential transformers which rotate recorder drum in proportion to motion measured. *Tinius Olsen Testing Machine Co., 1116 Easton Road, Willow Grove, Penna.*

Mention No. 418 when filling out card.

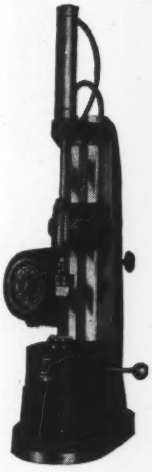
Field Altimeter

New "FA-181 Sensitive Altimeter," designed for severe field service, has shock-mounted mechanism in aluminum case which contains a desiccant to absorb moisture. Mechanism features self-balancing principle and custom calibration. "Palmer Altirule" computes elevations directly from observations when using two-base method.—*Wallace & Tiernan Products, Inc.*, 1 *Main St., Belleville* 9, *N. J.*

Mention No. 419 when filling out card.

Spring Tester

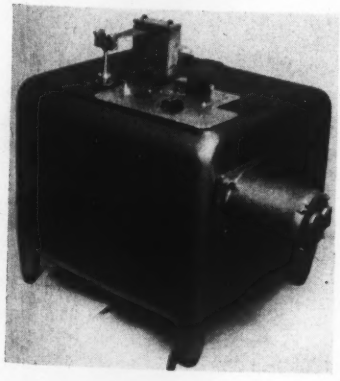
New pneumatic spring tester tests any resilient material with accuracy. Feature is non-deflecting weighing table, allowing use of a fixed stop in ram assembly, obviating need of reading height of compressed test piece, and leaving only load to be checked.—*Link Engineering Co.*, 13845 *Elmira Ave., Detroit* 27, *Mich.*



Mention No. 420 when filling out card.

Fatigue Tester

New table model of "Baldwin-Sonntag SF-2" fatigue machine is smallest of five standard models which now range in alternating force capacity



FINE SEAMLESS TUBING to PRECISION TOLERANCES

in Copper, Brass, Aluminum

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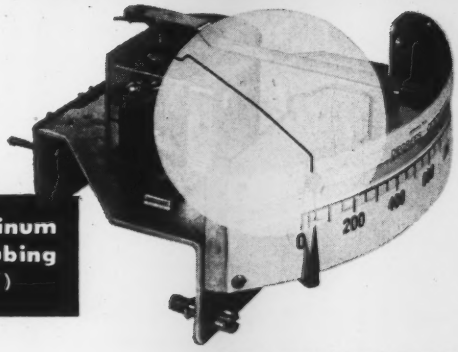
Any Wall Thickness



Specialists in Aluminum Alloy "Pointer" Tubing (walls to .0010")

Photo courtesy Brown Instruments Div., Minneapolis-Honeywell Regulator Co.

"Metal-Shielded Wire" (patented) also furnished. Write for information.

Finest quality "pointer" tubing in any size from .010" to .048" — choice of 6 aluminum alloys. Other seamless tubing up to 5/8" for gas or liquid applications or fabrication into special parts. While the bulk of our production is brass, copper or aluminum, we also draw nickel, steel, silver and other analyses.

With our new Collegeville plant, we have 2½ times previous production capacity, and in spite of defense demands, can still quote 2-3 weeks delivery on many orders.

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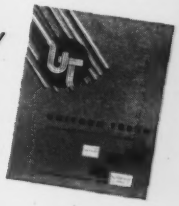

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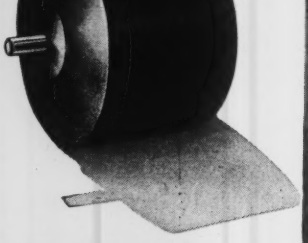

The Roto Steppers

provide 360° clockwise and counter-clockwise rotation in 2° increments as standard. Shaft output has sufficient torque to drive many low torque mechanisms, indicators, potentiometers, selsyns, synchros, switching devices and others. Features 24 volt system, long life solenoids and combinations.

AS LISTED BY PRODUCT NO. DIA. 3.13 IN.

Product No.	Case Lgth.	Shaft Output	Potentiometer Output	Homing Segments	Internal Auto Cycle
8915-1	2.25	√			
8915-2	3.25	√*	√		
8915-3	4.00	√*	√	√	
8915-4	4.00	√*	√	√	√

*AVAILABLE WITHOUT SHAFT OUTPUT

Write for Engineering Data

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Giannini

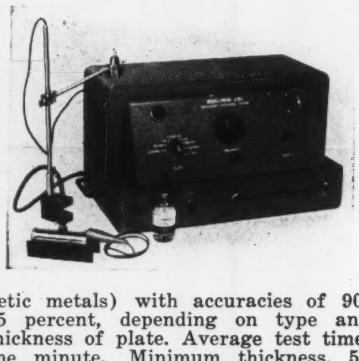
NEW INSTRUMENTS

from 25 to 10,000 lb. or from 50 to 20,000 lb. in one direction only. Maximum travel of loading yoke is 0.5 in. and testing speed is 1800 cycles per minute. Simulated service tests of small parts can now be made on new model whereas original machine was limited to sheet-metal specimens.—*Baldwin-Lima-Hamilton Corp., Phila.* 42, *Penna.*

Mention No. 421 when filling out card.

Coating-thickness Tester

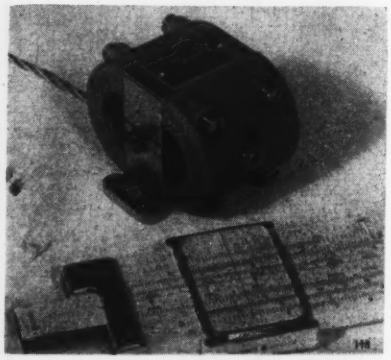
New "Model TT Electronic Thickness Tester" determines thickness of all common deposits on plane or curved surfaces of metal (including non-magnetic metals) with accuracies of 90-95 percent, depending on type and thickness of plate. Average test time, one minute. Minimum thickness, 50 microinches (5 microinches for chromium). Operation: instrument strips plate from small area (0.125-in. dia.) and then shuts off; thickness is read directly on counter.—*Dep't I, Kocour Co.,* 4800 *S. St. Louis Ave., Chicago* 32, *Ill.*



Mention No. 422 when filing out card.

Operator for Hydraulic Pilot Valves

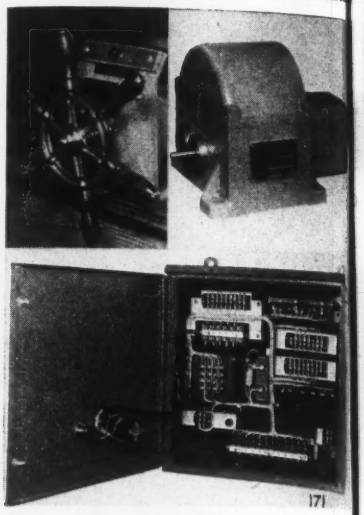
New "Model 8 Torque Motor," designed to stroke hydraulic servovalve pistons, is usually driven by servoamplifier utilizing two output tubes in push-pull; produces over 5 inch-pounds of torque at a radius of 0.906 inch with 40-ma. differential current in its two coils (2900 ohms each). Weight is 18 ounces; no-load natural frequency is 425 cps.—*Midwestern Geophysical Laboratory, Tulsa, Okla.*



Mention No. 423 when filling out card.

Steering Servo

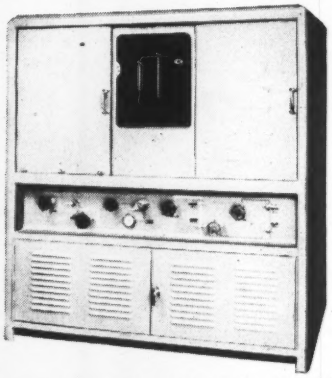
New "Fail-safe Ship Steering Ser System" controls rudder movement r motely from pilot-house steering whe through magnetic amplifier and h draulic servo system. Total moveme from hardover to hardover can be mad in less than 12 seconds. Failure o wiring will not cause rudder to mov from its position at time of fault. Manual operation of pilot valve is possible as electrical actuator is automatically disengaged when power is removed. No contacts or vacuum tubes are used.—*Bogue Electric Mfg. Co.,* 52 *Iowa Ave., Paterson* 3, *N. J.*



Mention No. 424 when filling out card.

Pneumatic Test Stand

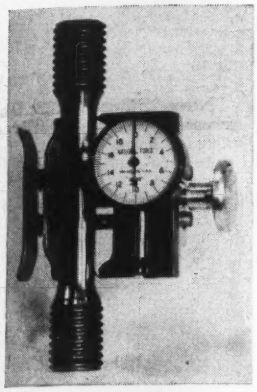
New "Model S-421" pneumatic test stand performs functional tests on components of aircraft and guided missile pneumatic systems; provides three separately-regulated test outlets with ranges of 0-200, 0-2000 and 0-6000 psi. Leakage flowmeters have ranges of 0.01 to 0.24 cfm. and 2 to 28 cim., respectively. Test area may be closed for safety by sliding quarter-inch thick steel doors. Twenty-inch square, two-inch thick, bullet-proof glass window is provided for observing tests. All controls may be operated with doors closed.—*Sprague Engineering and Sales Corp., Gardena, Calif.*



Mention No. 425 when filling out card.

Extensometer

New extensometer weighs 7 oz.; attaches to specimen by spring clamps which are opened or closed while held in palm of hand. Adjusts to take wire,

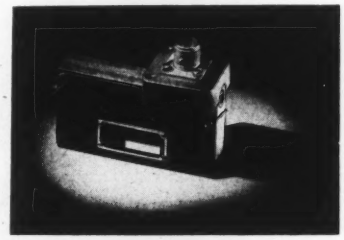


sheet, plate, or round specimens to maximum thickness or width of 0.5 in. Standard gage length is 2 in.; special, 1.4 in. Instrument indicates elongation to 0.045 in. in dial graduations of 0.0002 in.—*Testing Machine Div., National Forge and Ordnance Co., Irvine, Penna.*

Mention No. 426 when filling out card.

Liquid-level Switches

New level limit switches are magnetically operated, and use no springs. Fourteen models, embodying variations in mountings, materials, and floats



are available for aircraft use. Maker states that "weight and mass of non-absorbent nylon float are little affected by moisture." Switches are factory-set for high or low level control, or constant level maintenance.—*Revere Corp. of America, Wallingford, Conn.*

Mention No. 427 when filling out card.

Stroboscopic Light-source

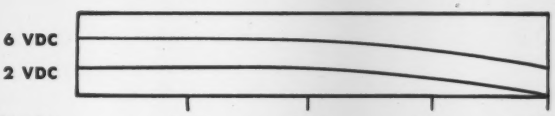
New "Model 18 Labstrobe" gives 60 brief flashes of light per second when connected to 60-cycle a.c. line. Standard neon bulb is readily obtainable

NOW FOR SPECTROPHOTOMETERS . . .

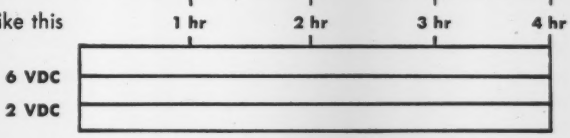
AN ISOTRONIC DC POWER SOURCE ACCURATE TO ±0.01%

Model E-6/2-5

The best of spectrophotometers operates erratically when input power looks like this



instead of like this



Haven't you been plagued by input voltage drop, particularly in the course of long-running experiments? Or have you had to interrupt or defer work while batteries were being charged or replaced?

The Sorensen Model E-6/2-5 Nobatron* has been specifically designed to exclude this difficulty. Using it, you can be sure your equipment is getting 2 and 6 volts DC, **plus or minus 0.01%,** with that accuracy maintained indefinitely at normal room temperature.

Furthermore, circuitry developed for the Model E-6/2-5 Nobatron is advanced in simplicity, involving no moving parts. That means easy maintenance, trouble-free operation. *Write for information.*

SPECIFICATIONS

Input voltage range	95-130VAC, 1Φ, 50-60 cycles
Output	
#1 for lamp	6VDC adjustable ±10% at 5 amperes
#2 for filament	6VDC at 100 Ma.
#3 for bias	2VDC adjustable ±10% at 100 Ma.
Filtering	
#1	1% max.
#2 & 3	0.05% max.
Regulation accuracy	±0.01% against line changes
Time constant	0.1 seconds under most severe line changes
Size:	17 x 12¼ x 17 self contained 19 x 12¼ panel for relay rack mounting
Weight:	Approximately 90 pounds
Meters:	No meters are provided due to the extreme regulation accuracy involved.

*Reg. U. S. Pat. Off. by Sorensen & Co., Inc.

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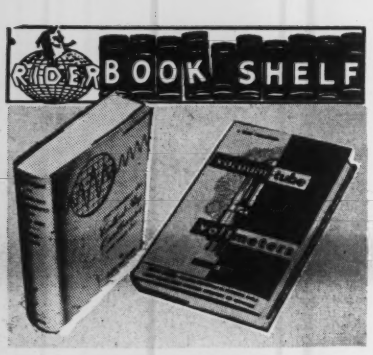

1. ENCYCLOPEDIA on CATHODE-RAY OSCILLOSCOPES and THEIR USES

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2. VACUUM-TUBE VOLTMETERS,

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NEW INSTRUMENTS

when replacement is needed. Duration of flashes is short enough to permit reading of a newspaper clipping rotating at 1800 rpm.—*Berkshire Laboratories, 550 Beaver Pond Rd., Lincoln, Mass.*

Mention No. 428 when filling out card.

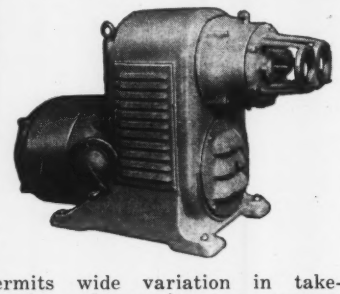
Dial Indicator

New "Model 145" dial indicator with jeweled bearings, said to be comparable to a precision timepiece, checks variations in contour, dimension, or roundness to one-ten-thousandth inch. Feature is Geneva movement, using lever arm instead of complexity of gears.—*Dept. AC, Chicago Dial Indicator Co., 180 N. Wacker Drive, Chicago, Ill.*

Mention No. 429 when filling out card.

Dual-head Test-stand

New test-stand for determining operating characteristics of aircraft generators, pumps, alternators, magnetos, compressors, etc., has dual head which

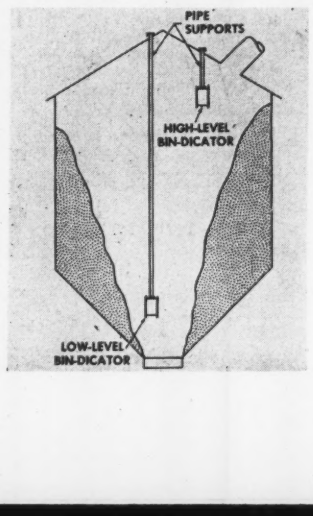


permits wide variation in take-off speeds and permits two component parts to be tested at one time. Variable-speed-motor horsepower for continuous duty is from 7½ to 50, and for intermittent duty from 10 to 75. Tachometer gives direct rpm. readings for both take-off shafts.—*U. S. Electrical Motors Inc., 200 E. Slauson Ave., Los Angeles 54, Calif.*

Mention No. 430 when filling out card.

Bin-level Indicator

New "Model CS Bin-Dicator," designed for suspended installation from above, can be located anywhere in bin where there is free flow of material to and away from diaphragm. Support

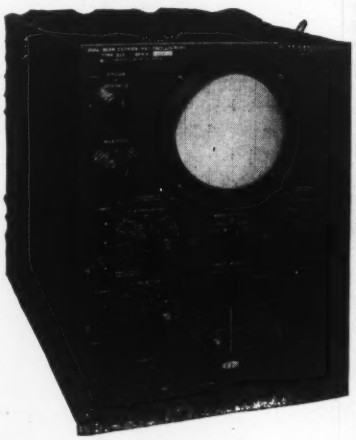


pipe (up to 2-in.) accommodates electrical wiring, making conduit unnecessary. Unit can be moved up or down to different levels or lifted out for inspection.—*The Bin-Dicator Co., 13946-201 Kercheval, Detroit 15, Mich.*

Mention No. 431 when filling out card.

Dual-beam Oscilloscope

New "Type 322 Dual-beam Oscillograph" is essentially two "Type 304-H" in a single cabinet. Tube is operated at accelerating potential of 3000



volts. Sinoidal frequency response of X and Y axes of both channels is down not more than 10 percent at 100 kc. and down not more than 50 percent at 300 kc. with a deflection factor of 0.028 peak-to-peak volts per inch on vertical axis and 0.28 on horizontal axis. Driven and recurrent sweeps are variable from 2 to 30,000 cps.—*Instrument Div., Allen B. DuMont Labs, Inc., 1500 Main Ave., Clifton, N. J.*

Mention No. 432 when filling out card.

Power Amplifier

New "Type 220-A Laboratory Power Amplifier" for laboratory and high-fidelity audio reproduction has rated power output of 20 watts and flat fre-

quency response from 12 to 55,000 cps. Harmonic distortion is less than 0.5 percent at 20 watts output; hum level is minus 90 db below full output.—*Hermon Hosmer Scott, Inc., 385 Putnam Ave., Cambridge 39, Mass.*

Mention No. 433 when filling out card.

Five-inch Oscilloscope

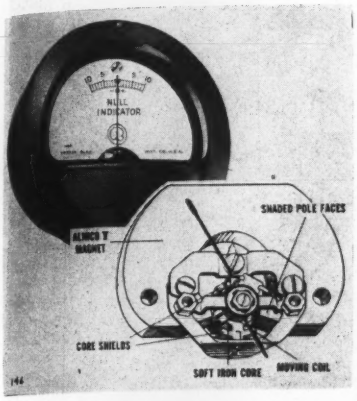
New "Model ST-2B" oscilloscope features identical high-gain direct-coupled vertical and horizontal amplifiers flat to 500 kc.; uses a driven sweep and

high accelerating voltage to permit use of tubes having long-persistance phosphors; has a low input capacitance (10 uuf.) probe and an internal voltage calibrator covering range of 0.1 to 300 volts peak to peak in eight steps. —*General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 434 when filling out card.

Null Indicator

New "Ruggedized" hermetically-sealed null indicator permits use of null system for precise measurement under field conditions. Center-point sensitivity is 1 ma. per mm. or higher, but

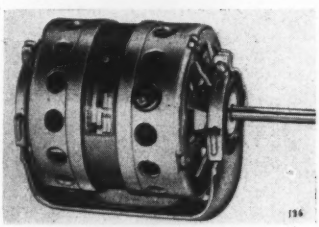


shaded pole face and shielded core give logarithmic attenuation as signal departs from null point, providing overload protection. Max. safe current is ten times full-scale value. Two sizes: 2.5 in. and 3.5 in., each available with numerous sensitivity and resistance characteristics.—*Marion Electrical Instrument Co., Manchester, N. H.*

Mention No. 435 when filling out card.

Fractional-hp. Motor

New "Model 3700 Cyclohm" induction motor, rated 0.04 to 0.25 hp., features resilient mounting base and quiet



operation. Hysteresis synchronous and normal induction types are available in 2-pole versions, both single-phase and polyphase.—*Howard Industries, Inc., Racine, Wis.*

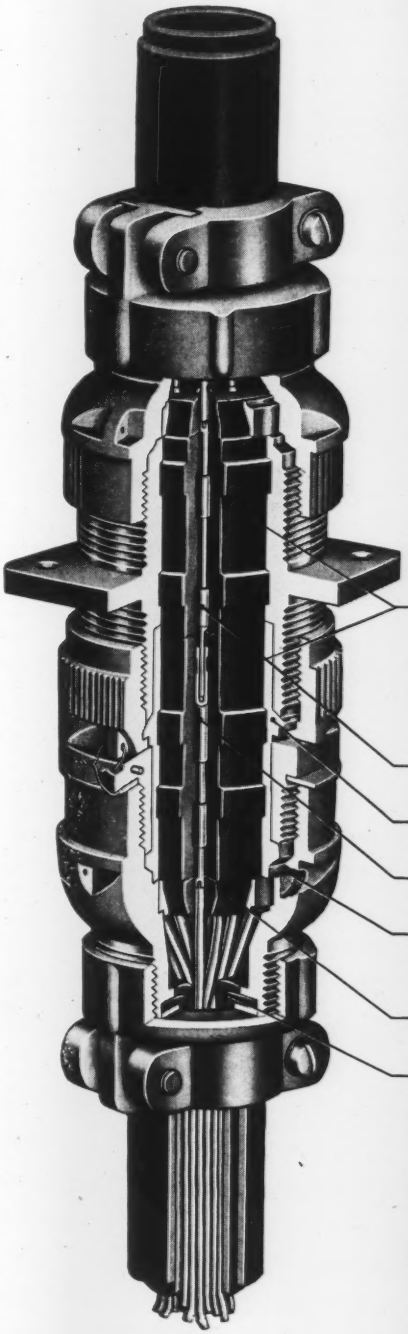
Mention No. 436 when filling out card.

Motion Measurement

New "Model 301 Differential Transformer Amplifier," designed for use with "Series O" Schaevitz linear variable differential transformers and accelerometers, permits static and dynamic measurements of displacement, force, vibration, torque, acceleration,

Here's why those in the know —demand

CANNON PLUGS



Here's another example of the meticulous care Cannon Electric uses in building connectors for highly specialized, tough jobs. This AN-"M" type connector is moisture-proof, vibration-proof and pressurized. Radio shielding is provided and every threaded part is drilled for safety wiring.

No corners are cut – nothing is overlooked to assure you outstanding performance. This connector is designed for aircraft use but there are more than 18,000 different Cannon Plugs made with the same care to serve the exacting needs of many industries. If you are looking for real value, regardless of the field you work in, your best bet is Cannon.

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Machined ball-in-cone joints provide radio shielding and improve vibration resistance.

Socket contacts machined from solid copper alloy with new Cannon design, silver-plated.

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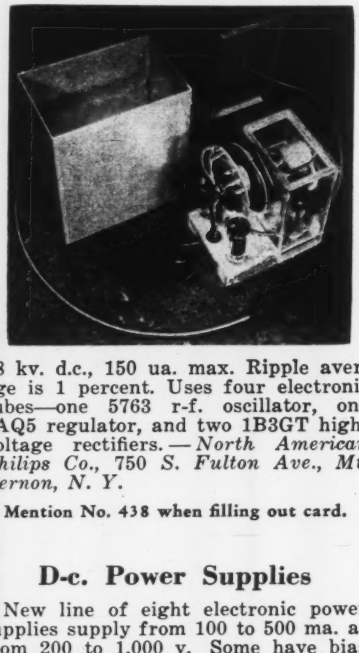
NEW INSTRUMENTS

etc. Instantaneous data may be presented on CRO screen; permanent records may be obtained with recording instruments. Freqeuncy response is from d.c. to 1000 cps. Amplifier is powered from 110 volts 60 cps.; has carrier oscillator to except primary of linear differential transformer.—*Sterling Instruments Co.*, 13331 *Linwood Ave., Detroit 6, Mich.*

Mention No. 437 when filling out card.

High-voltage Power Supply

New "Norelco" regulated high-voltage d-c. power supply is for use with cathode-ray and Geiger-counter tubes. Input is 315 v. d.c., 50 ma.; output is



18 kv. d.c., 150 ua. max. Ripple average is 1 percent. Uses four electronic tubes—one 5763 r-f. oscillator, one 6AQ5 regulator, and two 1B3GT high-voltage rectifiers.—*North American Philips Co., 750 S. Fulton Ave., Mt. Vernon, N. Y.*

Mention No. 438 when filling out card.

D-c. Power Supplies

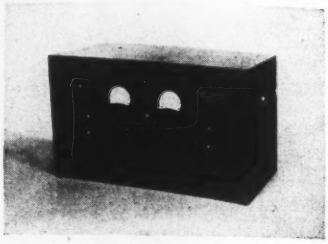
New line of eight electronic power supplies supply from 100 to 500 ma. at from 200 to 1,000 v. Some have bias voltage ratings either at 0 to 150 v. or 0 to 300 v. at 5 ma. Each model has

filament at 6.3 v. at either 3, 6, or 10 amps. Regulation is 0.5 percent; ripple voltage is 5 mv.—*The Perkin Engineering Co.*, 318 *Kansas St., El Segundo, Calif.*

Mention No. 439 when filling out card.

Dual Power Supply

New "Model ST-9A" dual regulated power supply has each supply independently regulated, controlled and indicated from 0 to 500 volts, and up to

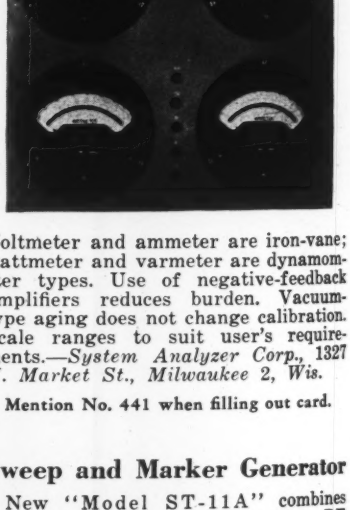


100 ma.; hum and noise below 3 mv. rms.; electronic overload protection for both tubes and indicators, bias voltages and a-c. filament supply. Regulated outputs may be modulated via an internal amplifier; and paralleled for increased current ratings.—*General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 440 when filling out card.

Electrical Indicating Instruments

New panel assembly of four high-grade 7-inch instruments, originally designed for an a-c. network analyzer, have accuracies within 0.25 percent.

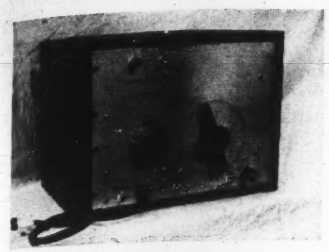


Voltmeter and ammeter are iron-vane; wattmeter and varmeter are dynamometer types. Use of negative-feedback amplifiers reduces burden. Vacuum-type aging does not change calibration. Scale ranges to suit user's requirements.—*System Analyzer Corp.*, 1327 *N. Market St., Milwaukee 2, Wis.*

Mention No. 441 when filling out card.

Sweep and Marker Generator

New "Model ST-11A" combines sweep signal and markers for RF alignment of television head-ends and over-all systems. Features: single-knob selection of sweep and from one to five marker frequencies simultan-

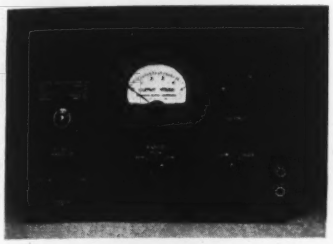


eously; continuously-variable capacitor-type attenuator with range in excess of 100 db; output 0.25 volt at 300 ohms balanced or 72 ohms unbalanced.—*General Electric Co., Electronics Park, Syracuse, N. Y.*

Mention No. 442 when filling out card.

Noise Generator

New "Type 1390-A Random-Noise Generator" utilizes a gas-discharge tube operated in a magnetic field as noise source. Two stages of amplifica-

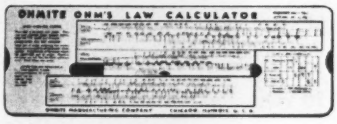


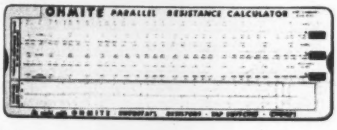
tion and suitable filters make it possible to have an open-circuit output voltage of one volt on three frequency ranges extending from 30 cps. to 5 Mc.—*General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.*

Mention No. 443 when filling out card.

Ohm's-law Calculator

New Ohm's Law Calculator is made of durable stable vinylite. Computing scales from Ohm's law are on front side; standard slide rule and parallel





-resistance scales are on back. Price is $1.50. Cardboard model is 25c.—*Ohmite Mfg. Co., 4937 W. Flournoy St., Chicago 44, Ill.*

Mention No. 444 when filling out card.

Voltage Tester

New "AD-100 Volt-A-Test" gives voltage readings up to 575 v. a.c. and 600 v. d.c. Safety is assured by three insulated coils in series; simultaneous breakdown of all three is remote. Ter-

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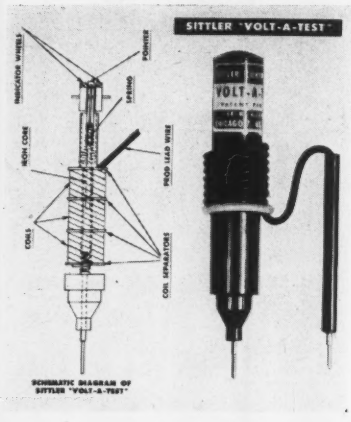
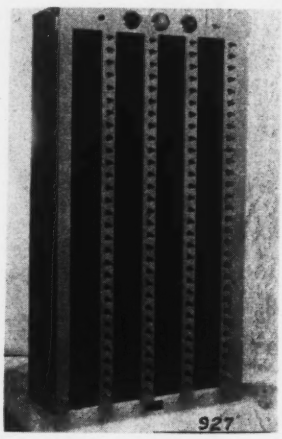


minals are separated by full length of coil; circuit is brought in at one end and out other end. Voltage indicator, located at end of case, comes into view; magnifying lens makes scale easy to read.—*Sittler Corp.*, 18 *North Ada St., Chicago* 7, *Ill.*

Mention No. 445 when filling out card.

Signal System

New "Type #MLBR, Design #JK, Service #200 Illuminated-Message Annunciator" is for power-plant use. Abnormal contact condition causes horn



audible signal and light message in red and white. When operator silences audible signal, red light remains until contacts restore to normal, which automatically causes a different tone signal (bell) to sound again and message is lighted in white, indicating restoration to normal.—*H. R. Kirkland Co., Morristown, N. J.*

Mention No. 446 when filling out card.

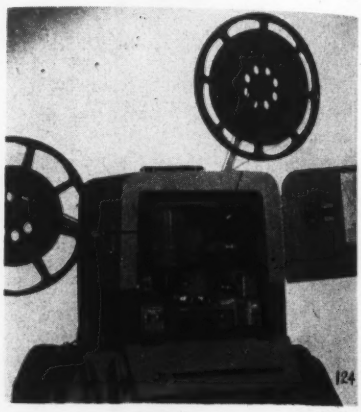
Cathode-ray Oscillograph

New "Type 293 Cathode-ray Oscillograph" employs sealed-off hot-cathode cathode-ray tube; is packaged as a single mobile console; eliminates elaborate preparation of oscillograph or recording materials. Special 35-mm. recording camera is supplied, or camera having object-to-image ratio of approx. 1 for full-scale records may be selected. Is applicable to laboratory impulse test programs and production testing of high-voltage equipment. — *Instrument Div., Allen B. DuMont Laboratories, Inc., Clifton, N. J.*

Mention No. 447 when filling out card.

Magnetic Sound-track Motion Pictures

New "Soundstripe" process for coating edge of 16-mm. film is announced together with new projector which records and plays back sound. With new



system, it is said that "a small manufacturer can make his own ten-minute sales or training film in sound and color for about $200 [whereas] professionally a similar film would cost $3,500."—*Bell & Howell Co.*, 7100 *McCormick Rd., Chicago* 45, *Ill.*

Mention No. 448 when filling out card.

Public-address Amplifier

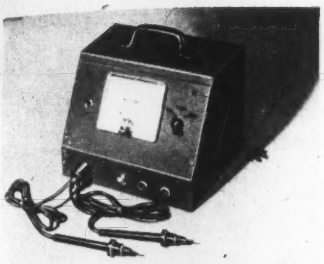
New "Knight" 80-watt public-address amplifier, designed for high-power paging and music distribution overcomes high noise levels, covers 260,000 sq. ft.,

and up to 40,000 people when used with proper accessories such as trumpet-type speakers.—*Allied Radio Corp.*, 833 *W. Jackson Blvd., Chicago* 7, *Ill.*

Mention No. 449 when filling out card.

Insulation Tester

New "Tesco" insulation tester features (1) safety, (2) instantaneous indication, (3) direct reading to 1000 megohms without calculation, (4) ability to discriminate between a complete insulation breakdown and leakage through insulation, and (5) portability

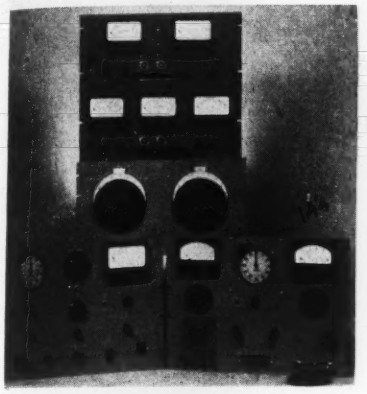


and compactness. Circuit consists of Sola constant-voltage transformer, step-up transformer, and rectifier-capacitor network that delivers a steady filtered voltage of 1500 volts d.c.—*Eastern Specialty Co.*, 3617 *N. 8th St., Phila.* 40, *Penna.*

Mention No. 450 when filling out card.

Test Panels

New test panels for production testing of gyros, amplifiers, servomotors, etc., include all necessary measuring instruments—time clocks, switches,



phase shifters, and cables. Units are designed by maker's engineering department or built to user's specifications.—*Sterling Instruments Co.*, 13331 *Linwood Ave., Detroit 6, Mich.*

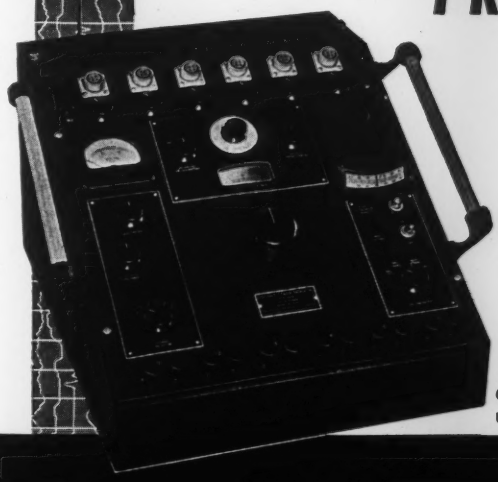
Mention No. 451 when filling out card.

Hydrocarbon Detector

New "MSA Aromatic Hydrocarbon Detector" indicates when concentrations exceed safe limits and has cylindrical scale graduated separately for benzene, toluene, and xylene. Stability of indicating material is assured by field

936

Measure and Record Strain with PRECISION



6-channel unit

The Hathaway TYPE RS-10 PRECISION STRAIN INDICATOR

6, 12, 25 or 50 Channels

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Static strain in 1 to 50 channels can be measured in rapid succession. Individually-calibrated 21-inch dial provides an accuracy of ¼ percent. Smooth and accurate balancing controls for each channel. Continuously-variable gage-factor adjustment.

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The RS-10 can be used with an oscillograph (such as the Hathaway type S14-C) for recording dynamic strain, providing *accurate balancing* and means for *precision calibration of the records.*

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NORTH AMERICAN AVIATION, INC.

Aerophysics, Electro-Mechanical Research Division

Personnel Section, 12214 Lakewood Blvd. Downey, California

NEW INSTRUMENTS

filling of detector tubes. Unit comprises color scale, tube rack, mixing bottle, mandrel, rubber tube caps, and kit for 12 separate tests.—*Mine Safety Appliances Co., Braddock, Thomas and Meade Sts., Pittsburgh 8, Penna.*

Mention No. 452 when filling out card.

Lens Comparator

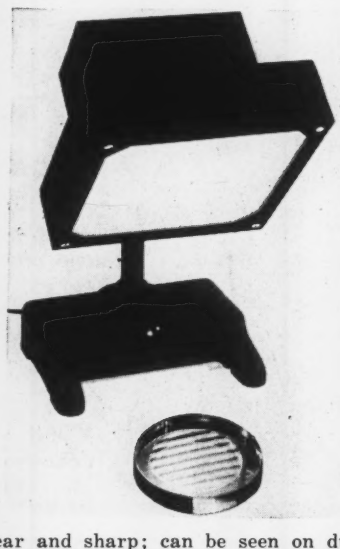
New "Animar Lens Demonstrator" is revolving turret that accommodates three 8-mm. or 16-mm. lenses. By focusing on subject, and revolving turret

from lens to lens, one can compare high-speed lens, normal lens, etc.—*Bausch & Lomb Optical Co., 635 St. Paul St., Rochester 2, N. Y.*

Mention No. 453 when filling out card.

Monochromatic Light Source

New monochromatic light for measurements with optical flats has large working field to obviate exact placement of work. Interference bands appear



clear and sharp; can be seen on dull surface or through air gap; each means a vertical-height change of 0.0000116 inch and can be interpreted to one microinch.—*Acme Scientific Co., 1457 W. Randolph St., Chicago 7, Ill.*

Mention No. 454 when filling out card.

Angle-head Centrifuge

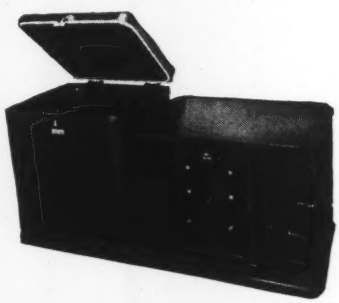
New 1550-rpm. centrifuge is for fast individual tests. All rotating parts are concealed by aluminum guard. Angle-type rotor has openings to receive four

15-ml. metal shields supplied with centrifuge. Four 15-ml. glass tubes also are provided.—*The Scientific Glass Apparatus Co., Inc., Bloomfield, N. J.*

Mention No. 455 when filling out card.

Cold Test Cabinet

New "Sub-Zero W-120" has a capacity of five cubic feet; will maintain temperatures as low as −120 F. At this temperature it will remove 500

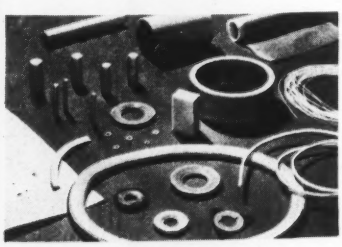


Btu's per hour, equivalent of cooling 20 lbs. of steel from room temperature to −120 F.—*Sub-Zero Products Mfg. Div., Deepfreeze Distributing Corp., Cincinnati 29, Ohio.*

Mention No. 456 when filling out card.

Teflon Gaskets and Packing

New line of Teflon gaskets and packing is announced, as well as Teflon



sheet, tape, cylinder, rod, tube, bar stock, etc.—*Packing Div., Flexrock Co., 3609 Filbert St., Phila. 4, Penna.*

Mention No. 457 when filing out card.

Monochromatic Light Source

New "DoAll Monolight" has 10 times capacity of previous model. Adjustable 5x5½ in. high-intensity helium-tube light source provides 53 foot-candle

power on testing stage. With optical flats it can measure size, flatness, and parallelism to a few millionths of an inch. Accessories include gage blocks and optical flats.—*DoAll Co., 254 North Laurel Ave., Des Plaines, Ill.*

Mention No. 458 when filling out card.

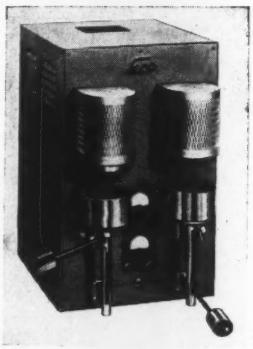
Pressure Controller

New model of maker's "Pressuretrol" for low-pressure domestic steam boilers is of low cost by reason of mass production. Concealed fixed adjustment prevents owners from tampering with setting.—*Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.*

Mention No. 459 when filling out card.

Analysis Furnace

New "Model IH-15" induction furnace is a two-combustion-tube unit designed for carbon and sulphur analy-

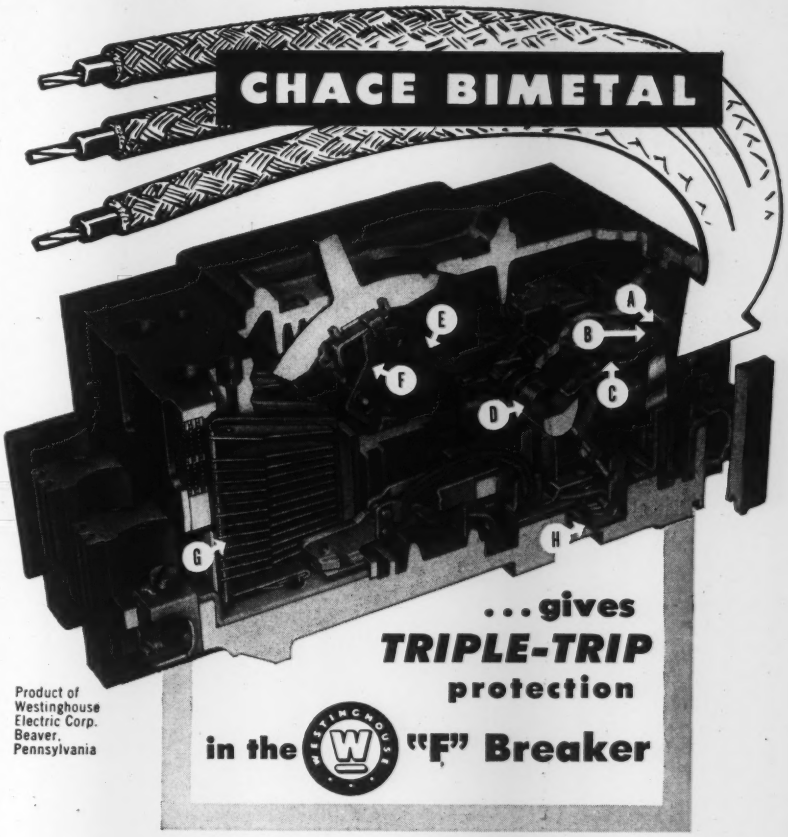


ses: one sample can be combusted while other sample is weighed and loaded.—*Laboratory Equipment Corp., St. Joseph, Mich.*

Mention No. 460 when filling out card.

Beranger-type Balance

New one-pan Beranger-type balance features fast weighing and mechanism with no loose weights. Single beam weight is moved along beam for rough balance, final adjustment is made on micrometer which is an integral part



Product of Westinghouse Electric Corp. Beaver, Pennsylvania

The Westinghouse "F" Frame Circuit Breaker is a 3-pole type so designed that when a fault occurs on any one of the three lines, *all three* contacts open and current flow stops. The Trip Bar is made common to all three lines, and each line is protected by a complete set of circuit breaker components, including a magnetic trip element and a Chace Thermostatic Bimetal trip element. One of the desirable features of this protective device is the exclusive "DE-ION" Arc Quencher for fast, sure circuit arc extinction.

The versatile Chace Bimetal action is best suited to temporary overloads—with relatively long delay on light overloads and short delay on heavy overloads. When a sustained overload is on the circuit the current heats the Bimetal Trip Element (A) causing it to flex toward the low responsive side in the direction of the load terminal. The Latch (B) slides off the Transfer Arm (C) which pivots under pressure of its spring, pressing down the Trip Bar (D), causing it to rotate and release the Trip Actuating Arm (E). This allows the Trip Toggle Mechanism (F) to operate and open the contacts. Arc interruption is aided here by "DE-ION" Arc Chutes (G). The magnetic action (H) causes "snap-action" and the instantaneous breaking of short-circuit currents.

If the actuating element for your new control device is thermostatic bimetal, Chace is equipped and qualified to fabricate it ready for assembly. Our 29 types are also available in strips, coils, random long lengths and welded or brazed sub-assemblies. We invite you to consult with our application engineers—recognized authorities on temperature responsive devices. Write for our 64-page reference on the selection and design of thermostatic bimetal elements.

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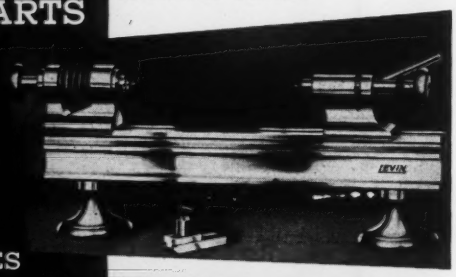
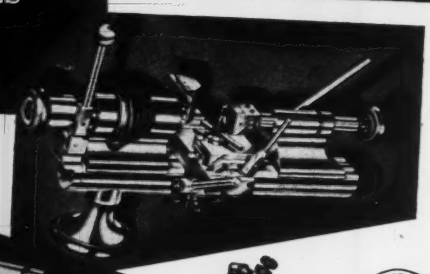
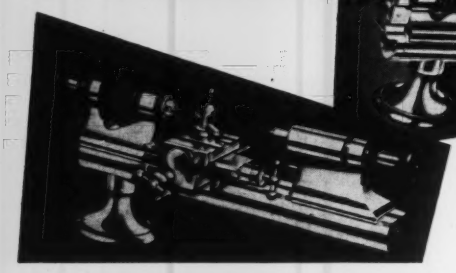
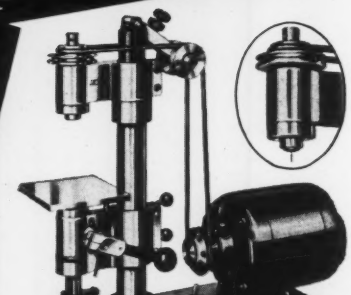
Ideal for second operations or experimental work on small instrument parts where sensitivity is required. Releases expensive, larger lathes for more suitable work. Full line of accessories available.









An extremely sensitive drill press for very small drills down to .002". Drills held in accurate collets to minimize deviation. Spindle run-out less than .0001". Finger tip control enables operator to feel progress of drill.

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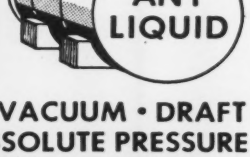
FOR MEASURING TANK CONTENTS ANY DISTANCE AWAY



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BAROMETRIC PRESSURE
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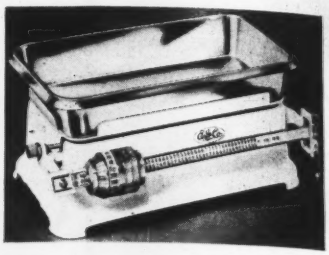
NEW INSTRUMENTS

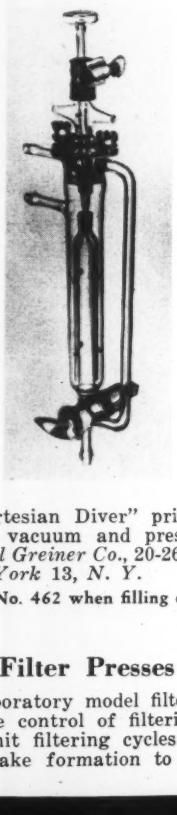


of beam weight. User reads kilos and grams on beam and adds micrometer reading. Flat plate or pan available on large-size balance. Capacities are to 14 kg.—*The Emil Greiner Co.*, 20 *N. Moore St., New York* 13, *N. Y.*

Mention No. 461 when filling out card.

Pressure and Vacuum Controller

New "No. 7" all-glass model of maker's "Cartesian Manostat" is especially suitable for laboratory application because of its resistance to corrosion.

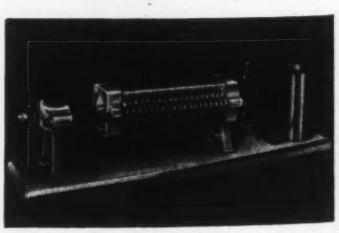


Uses "Cartesian Diver" principle for automatic vacuum and pressure control.—*Emil Greiner Co.*, 20-26 *N. Moore St., New York* 13, *N. Y.*

Mention No. 462 when filling out card.

Filter Presses

New laboratory model filter presses for precise control of filtering operations permit filtering cycles and rate of filter cake formation to be deter-

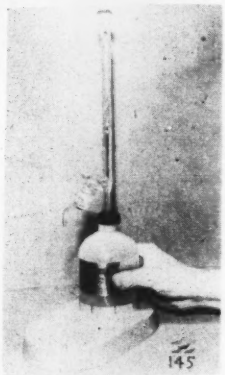


mined precisely. Of aluminum construction, laboratory model has slurry tank and is equipped with single-phase motor and pump.—*Valley Foundry and Machine Works, Inc.*, 2718 *East Ave. at Highway* 99, *Fresno, Calif.*

Mention No. 463 when filling out card.

Automatic Burette

New "Squeez-O-Matic" burette unit features a polyethylene reservoir which requires only a squeeze to fill an automatic self-leveling burette. Another



feature is special base which holds plastic bottle and provides platform for beaker, flask, or dish. Available in 25 and 10 ml. sizes graduated to 0.1 ml.—*Hagan Corp.*, 323 *Fourth Ave., Pittsburgh, Penna.*

Mention No. 464 when filling out card.

Washfastness Test

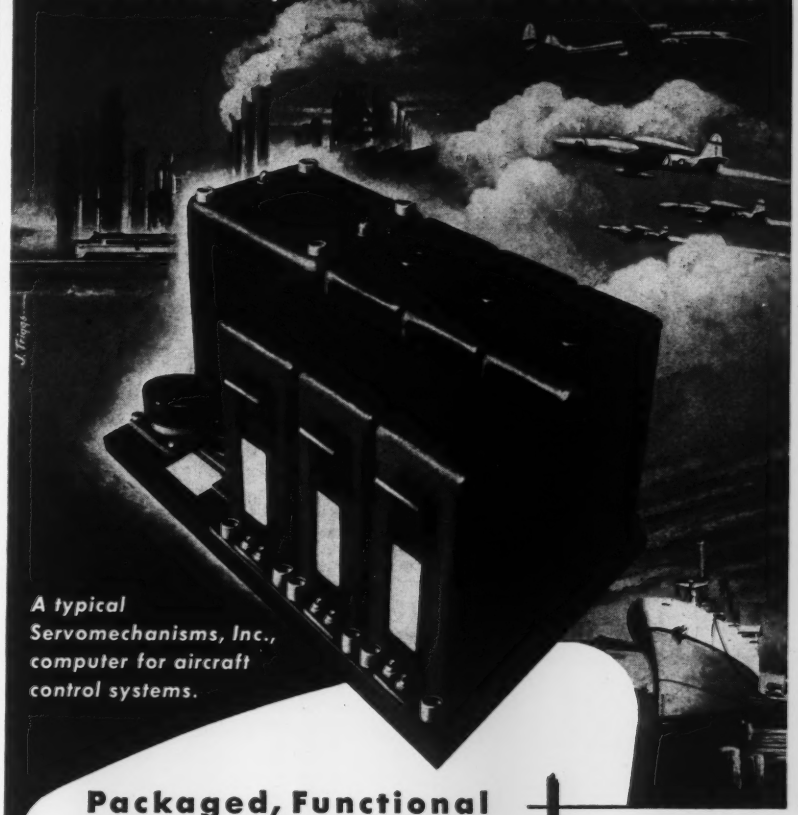
New specimen containers for No. 3A Tentative Accelerated Washfastness Test subjects test specimens to a forceful throw, a long slide, and a strong impact. Test is applicable to cotton or linen textiles.—*Atlas Electric Devices Co.*, 361 *W. Superior St., Chicago* 10, *Ill.*

Mention No. 465 when filling out card.

Combustion Boats

New sample package, available on request, contains blank-free combustion boats that will not crack or burn-through even during high-temperature

PACKAGED, Functional Electronics



A typical Servomechanisms, Inc., computer for aircraft control systems.

Packaged, Functional Electronic Controls for Defense and Industry

Servomechanisms, Inc.,...pioneers in the design and production of packaged function "building blocks" for electronic and electro-mechanical control systems. Each block in the system is an individually packaged function easily plugged-in or out of pre-wired chassis. This technique simplifies maintenance and reduces the "down-time" problem to minutes. Both 60 and 400 cycle blocks are available for system synthesis. Servomechanisms' packaging technique provides the military and industrial designer with:

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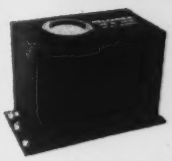

MECHANISMS—COMPUTERS

AMPLIFIERS—ADAPTERS

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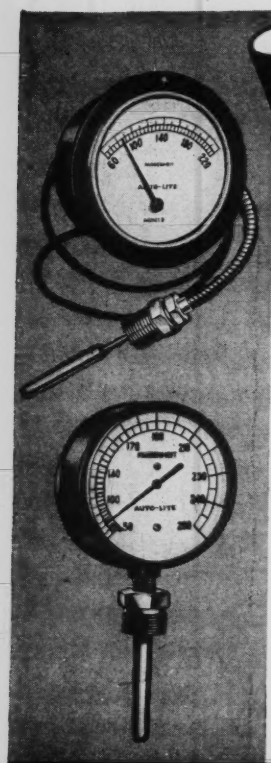

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FOR TEMPERATURE INDICATION

Auto-Lite Thermometers are designed to give you the broadest selection for your needs: Priced low and precision-made for accuracy, these instruments point the way to temperature savings and help to prevent spoilage. Write for catalog showing the many styles and types of Auto-Lite Thermometers that are available.

TYPICAL APPLICATIONS: STORAGE TANKS & ROOMS, COOLERS, DRYERS, AIR CONDITIONING, PILOT PLANTS.

Illustrated, at top: Model G Indicating Thermometer, flush mounting type with capillary tubing for remote reading. Priced from $18. At bottom: Model V Thermometer (vapor pressure type). Rigid stem for direct mounting. Priced from $10.25.

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THIS IS IT!

World-wide recognition for this outstanding line of electric soldering irons —

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★ MINNEAPOLIS HONEYWELL
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PLUG OR SCREW TIPS
40 to 700 Watts
⅛" to 1¾" Tip Dia.

Follow the leaders and you'll specify HEXACON! They'll efficiently solve your soldering problems too! Write for literature.

Here's the famous
HEXACON HATCHET TYPE

These irons feature better balance for reduced operator fatigue. Efficiency is stepped up, and quality of work is improved. The ideal iron for inaccessible and intricate jobs.

HEXACON ELECTRIC CO.
179 W. CLAY AVE. ROSELLE PARK, NEW JERSEY

NEW INSTRUMENTS

tests above 2400 F. Used for holding steel samples during carbon and sulfur determinations. Sample area is 80 x 8 x 6 mm.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 466 when filling out card.

Polyethylene Bottles

New "Plaxpak" polyethylene bottles, adopted for packaging buffer solutions used to standardize Beckman pH meters, eliminate selective leaching of

glass bottles by solutions. Also eliminates breakage due to impact or freezing.—*Plax Corp., Hartford, Conn.*

Mention No. 467 when filling out card.

Solution Tester

New "GS#112 Freezmeter" tests anti-freeze solutions based on temperature of solution being tested. Chart gives freezing point of all three popular radiator solutions. Thermometer is built in.—*General Scientific Equipment Co., 2700 W. Huntington St., Philadelphia 32, Penna.*

Mention No. 468 when filling out card.

Pipette Washer

New model of maker's pipette washer features stainless-steel basket. Pipettes cannot protrude beyond sides of holder to be chipped or broken while being washed. Has a glass cleaning chamber with an integral automatic syphon; is used for flushing and rinsing; soaking and cleaning are done in separate jar.—*Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Penna.*

Mention No. 469 when filling out card.

Instrument Current Transformers

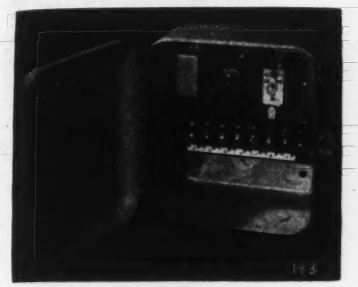
New "Model 321 Donut" instrument current transformers for use with inserted primaries have O.D. of 5.0 in., I.D. of 2.25 in. and thickness of 1.75 in. Capacity is 2.5 volt-ampere. Accu-

racy is 1.2 percent at full rated capacity. Phase-angle error is between zero and plus two degrees. Frequency is 25 to 133 cycles; higher frequencies can be supplied on special order. Insulated for use on 2400-volt rms. service. —*Associated Research Inc., 3766 W. Belmont Ave., Chicago 18, Ill.*

Mention No. 470 when filling out card.

Electronic Prime Relay

New electronic relay utilizes an unlimited-life cold-cathode triode (TT-1) with operating current of two microamperes. Current amplification up to



2.5 million is obtainable. Relay utilizes 115-v. 60-cps. power source, consumes 2 watts when in operation, does not require warm-up.—*Haledy Electronics Co., 57 William St., New York, N. Y.*

Mention No. 471 when filling out card.

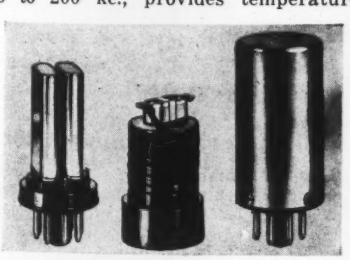
Printed-circuit Paint

New "SCF-12 Firing Type Silver Micropaint" is for use on heat-resistant ceramic surfaces where highest conductivity and good solder bond are required. It is applied by silk-screen stenciling, brush or spray stenciling, brushing, dipping, etc.—*Micro-Circuits Co., New Buffalo, Mich.*

Mention No. 472 when filling out card.

Crystal Oven

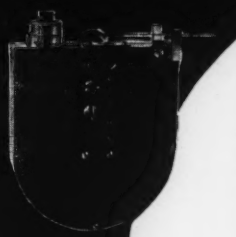
New "JKO-2T" miniature crystal temperature control oven, for crystal units normally in frequency range of 16 to 200 kc., provides temperature



Edin instruments

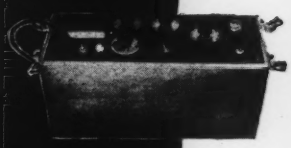
OSCILLOGRAPH GALVANOMETER

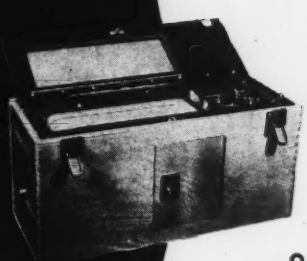
No's. 8001, 8002, 8003 and 8004 ink-writing galvanometers have sensitivities from 3.5 to 40 volts per cm., resonant frequencies from 15 to 120 cps., resistances from 1000 to 2000 ohms, frequency response up to 350 cps., and a single-jewel pivot construction. Units are designed for multiple operation up to 10 channels in a total width of 12 inches.



DIRECT-COUPLED AMPLIFIER

No. 8100 direct coupled amplifier has a voltage amplification of 13,000 with a maximum output of 70 volts. Frequency response from d.c. to 10,000 cps. is flat within 10%. Input impedance is 2 megohms; output impedance is 150 ohms. Input may range from 0.1 mv. to 100 volts. Stability is better than 0.1 mv. per thirty minutes, or 0.5 mv. per day. Attenuator is stepped for factors from 1 to 1000.





OSCILLOGRAPHS

Recorders can be supplied with 1, 3 or 9 chart speeds ranging from 0.1 mm./sec. to 250 mm./sec. See specifications of OSCILLOGRAPH GALVANOMETER for frequency range.

OSCILLOGRAPH AMPLIFIER

No. 8121 special amplifier has a time constant of 1 second, an exponential response to a square wave at high gain, input impedance of 1 megohm, and input form 0.1 mv. to 1000 volts. At low gain, No. 8121 becomes a DC amplifier with a voltage gain of 100 and an input of 10 mv./mm.

HIGH-GAIN AMPLIFIER

No. 8130 amplifier has a voltage gain of 1,000,000 and includes a built-in pre-amplifier. Frequency response is from 1 to 200 cps. Input may range from 10 microvolts to 100 millivolts. This amplifier is particularly suited for Biological studies.

Many other types of recording and amplifier circuits are available and special equipment can be assembled to meet particular specifications.

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☐ RECORDERS
☐ NO. 8121 AMPLIFIER
☐ GALVANOMETERS
☐ No. 8100 AMPLIFIER
☐ No. 8130 AMPLIFIER
☐ _____ SPECIAL (Enclose details)

_____ (NAME)

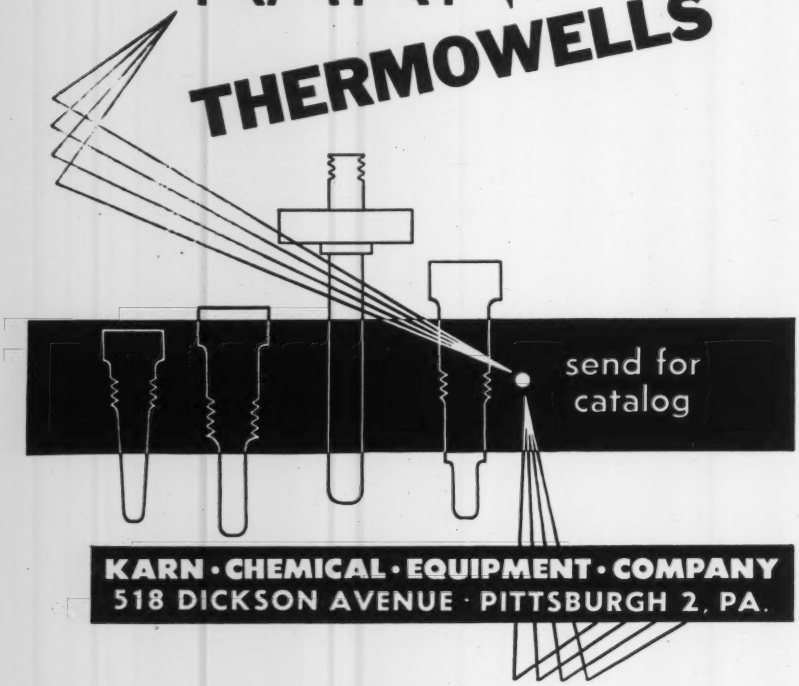
_____ (NO.) _____ (STREET)

_____ (CITY) _____ (STATE)

_____ COMPANY _____ POSITION

KARN

THERMOWELLS



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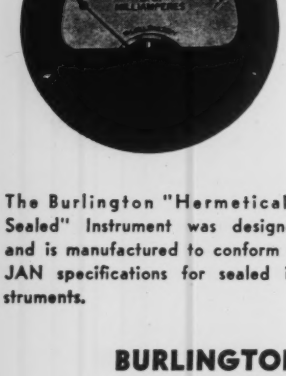


The Burlington "Hermetically Sealed" Instrument was designed and is manufactured to conform to JAN specifications for sealed instruments.

Burlington

HERMETICALLY SEALED INSTRUMENT

- Steel case with heavy copper-cadmium plate and black finish.
- Excellent shielding due to case material and construction.
- Double strength clear glass.
- Black satin onodized aluminum bezel.
- Glass to metal seal under controlled humidity and temperature conditions.
- D'Arsonval permanent magnet type movement for DC applications.
- Designed to enhance panel appearance.
- Available in 1½" square, 2½" and 3½" round case types.
- Guaranteed for one year against workmanship and materials.

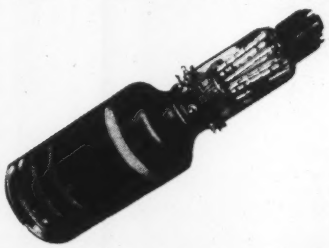
BURLINGTON INSTRUMENT COMPANY
Dept. H-42, Burlington, Iowa

stabilization at 75 C. plus or minus 2 deg. for one or two "Type H-17T" (Military Type HC-13/U) crystal units in ambients from −55 to +70 C. Standard octal base; over-all width, 1.28 inches; height, 2.41 inches.—*James Knights Co., Sandwich, Ill.*

Mention No. 473 when filing out card.

Two-gun CR Tube

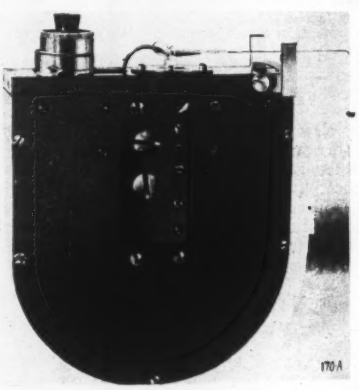
New "Type 52HAP7" two-gun multipost accelerator band cathode-ray tube is similar to RTMA "Type 5SP7" except for operation at higher accelerating voltages; 25,000 volts d.c. can be applied to accelerator anode. New aluminized screen permits greater luminous efficiency at accelerating voltages above 5,000 volts.—*Electronic Tube Corp., 1200 East Mermaid Lane, Phila. 19, Penna.*



Mention No. 474 when filling out card.

High-speed Galvanometer Element

New "Model 8004" galvanometer element with ink pen has good frequency response to 350 cps. and sensitivity of 40 v./cm. Coil resistance is 1500 ohms. Auxiliaries include d-c. and a-c. amplifiers. Supplied for any recorder or in multi-channel oscillographs.—*Edin Co., 207 Main St., Worcester 8, Mass.*



Mention No. 475 when filling out card.

Telemetering Commutator

New "Mycalex 410" telemetering commutator plate, which has logged well over 1,000 hours of high-speed clean-signal telemetering service, samples 60 channels of information. Com-

plete miniature telemetering switch illustrated is supplied for either 28-volt d.c. or 8-volt 400-cycle a.c. For a.c., a selenium rectifier is imposed in circuit.—*Mycalex Corp. of America, 30 Rockefeller Plaza, New York 20, N. Y.*

Mention No. 476 when filling out card.

Magnetic Converter-amplifier

New 3-oz. magnetic converter changes low-level d-c. signals to a-c. voltage. Case is metal envelope of standard 6L6 tube. Bridge circuit has two in-

ductors and is energized by 6.3-v. 400-cps. power. Small d-c. voltage then causes 800-cps. second-harmonic output signal. Converter can be used at other frequencies by selecting external capacitor which tunes output. Magnitude of 800-cps. output voltage varies linearly with d-c. input from 0 to 10 millivolts. Gain is from 30-1 to 100-1.—*Meter & Instrument Dep't, General Electric Co., 40 Federal St., West Lynn 3, Mass.*

Mention No. 477 when filling out card.

Thermistor Paints

New temperature-sensitive resistor paints can be used as temperature-measuring elements, time-delay devices, protective devices, etc. Among characteristics: (1) many power ratings; (2) no time-lag apparent; (3) wide range of coefficients; (4) resistance at 300 F. may be 1/30 of res. at 70 F.; (5) materials not critical; (6) low cost.—*Micro-Circuits Co., New Buffalo, Mich.*

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Toroidal Inductors

New toroidal loading coils for impedance matching between open wire lines and cables are applicable at carrier frequencies of 3 to 35 kc. Basic

NOW...9000 records per minute!
with the NEW POTTER high speed
TELEDELTOS RECORDER

IMMEDIATELY VISIBLE
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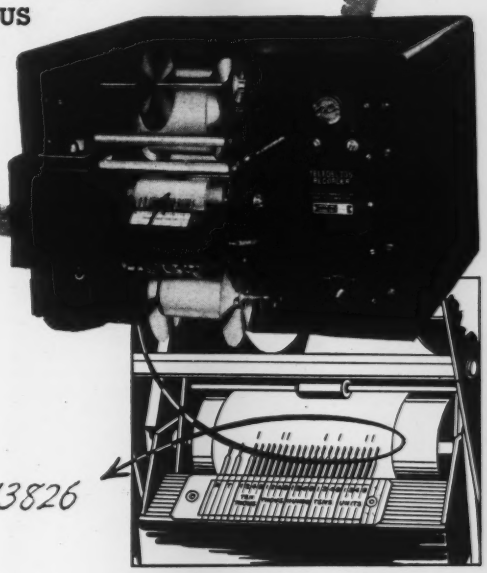
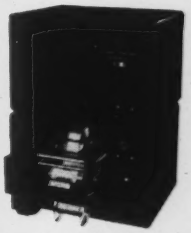


Designed to record measurements obtained on Potter Electronic counters, scalers, chronographs and frequency-time counters.

The Potter Instrument Co. High Speed Teledeltos Recorder provides a permanent recording of digital information at rates up to 150 six-digit answers per second. The measurements are transferred to electrically sensitive paper using four stylii for each digit arranged in the famous Potter (1-2-4-8) read-out. The records are indexed intermittently and controlled by the events being measured.

Write for information on specific applications to Dept. 4C.

POTTER RECORDING COUNTER CHRONOGRAPH



Measures time intervals up to 0.10000 second in increments of 2.5 microseconds. (Higher resolutions are also available.) Applicable to projectile velocity measurements, frequency measurements, geophysical measurements, telemetering and wherever micro-second timing is required.

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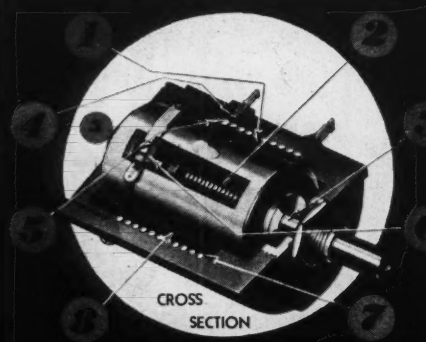
MICROPOT

PRECISION TEN-TURN POTENTIOMETER

1. You get permanent accuracy because the resistance wire is locked in place. It is precision positioned and moulded integrally with the housing.
2. You get permanently accurate settings, smooth action and low uniform torque provided by the stainless steel, precision ground, double thread lead screw guiding the moving contact.
3. You get precise positioning of the moving contact because of the two bearings supporting the rotor assembly.
4. You get good rigid terminals because they are moulded integrally with the housing.
5. Terminals soldered to ends of resistance element before moulding. Entire resistance circuit is an integral part of the housing.
6. You get accurate setting and resetting due to anti-backlash spring in contact guide.
7. You get a fine resolution because of the 43½" length of resistance wire in the spiral element.
8. You get a resistance output directly proportional to shaft rotation within ±0.1% of the total resistance. Every potentiometer is automatically machine tested for linearity at 101 points.



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Units for immediate shipment:
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Special resistance values made to order.

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NEW INSTRUMENTS

coils have inductance of 4.3, 2.6, and 4.1 millihenries within 0.02 mh. Windings are balanced to 0.1 percent of inductance from 200 cps. to 35 kc. Maximum resistance unbalance is 0.03 ohm; current rating is 300 ma.; insulation withstands 3500 volts rms.—*Lenkurt Electric Co., 1105 County Road, San Carlos, Calif.*

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Miniature Transformers and Reactors

New line of miniature hermetically-sealed low-frequency transformers (input, interstage, and output) and reactors is announced. Standard tolerance is 5 percent of master standard; special tolerance is 1 percent. Other features: True hermetic seal and mu-metal cases. Initial production comprises five types of transformers and four types of reactors; others to be available in 1952.—*Southwestern Industrial Electronics Co., P. O. Box 13058, Houston 19, Texas.*

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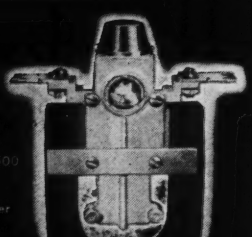
Specify... GM

D'ARSONVAL PORTABLE

GALVANOMETERS

AND MOVEMENTS...



Ideal as a built-in component of other instruments—with the sensitivity and ruggedness that is especially desirable for Colorimetry, Densitometry, and various other measurements. Unit includes mirror movement, magnet and zero correction knob. Choice of 4 standard models.

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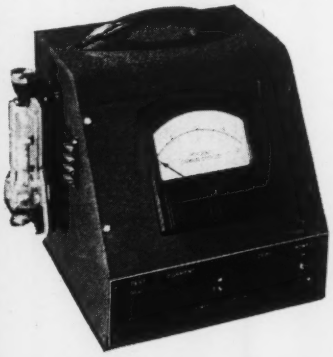

A **portable** and **continuous reading** CO_2 Indicator with no chemicals to replace or liquids to manipulate. It draws its own sample and gives the analysis in a few seconds. The readings quickly follow burner or damper adjustments permitting an optimum setting in a minimum of time. This instrument is economical, requires no installation expense, and saves fuel and labor.

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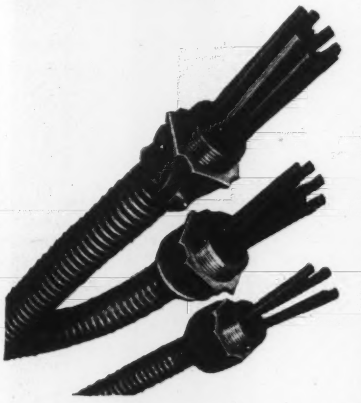
"Industrial Instrumentation for Gas Analysis"

Control-circuit Cable

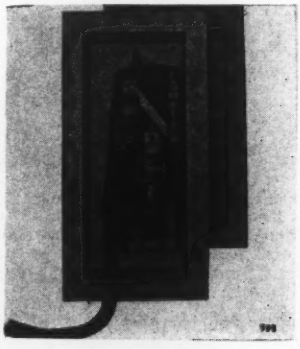
New "Armortube Cable" is flexible, protected multi-tube transmission line made up of 0.25-in. O.D. aluminum or copper tubing, wrapped in water-repellant insulating tape, then encased in heavy rust-resistant galvanized steel strip. It is available in bundles of 4, 8 and 12 tubes for hydraulic control pressures as high as 3000 psig. and all ranges of pneumatic control pressures. Connections and take-offs may be made in standard electrical junction boxes. A tracer tube identifies corresponding tube ends between cable-connecting points.—*Bailey Meter Co.*, 1022 *Ivanhoe Rd., Cleveland* 10, *Ohio.*



Mention No. 481 when filling out card.

Remote Control Relay

New relay combining lightning arrestor and fused coil and load circuits with standard 30-amp. mercury plunger relay is offered with or without fuses and arrestor for street-lighting circuits. Available for normally-closed or normally-open pilot circuits, relay is hermetically sealed in a glass tube. Make and break surfaces are large areas of mercury.—*H-B Instrument Co.*, 2633 *Trenton Ave., Philadelphia* 25, *Penna.*



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Magnetic Starters

New line-voltage-type a-c. magnetic starters in sizes 0 and 1 have easily accessible parts. Contact carrier and contact blocks are molded of arc-resistant Melamine. Overload relay features

MICRODIAL

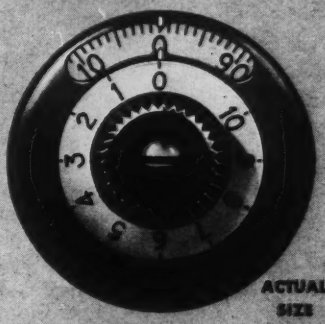
TEN TURN-COUNTING DIAL

Microdial is composed of two concentrically mounted dials . . . one for counting increments of each turn and the other for counting turns. The incremental dial has 100 equal divisions and is attached rigidly to the shaft so there is no backlash. Thus the contact position is indicated to an indexed accuracy of 1 part in 1000. Rotation is continuous in either direction. There are no stops on the Microdial assembly.

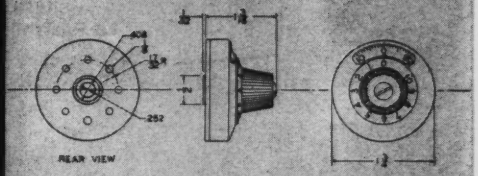
COMPACT . . . Microdial has same O.D. as Micropot . . . requires no more panel space.

CLEAR READING . . . Forced fast-reading tests showed only 1/20th as many errors with Microdial open window as with next most legible dial. Turn counter distinguishes between 0 and 10 turn readings, and accelerates to avoid confusion on readings near integral turns. Precise readings are made from larger dial with maximum separation of graduations and wide angle visibility.

CONVENIENT . . . delivered completely assembled with dials synchronized. Easily mounted in a few seconds. All dials may be locked.



ACTUAL SIZE



REAR VIEW

Microdial . . . turn-counting dial, primarily designed for use on Micropot ten turn linear potentiometers . . . use it on any multiturn device having ten turns or less.

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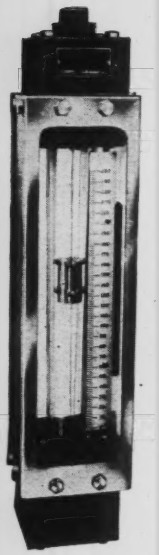

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8 stainless steel dowel pins precisely align the side plates and end fittings and are the *keys* to quick, trouble-free assembly and maintenance. The metering tube is installed after the frame is completely assembled. Tube breakage due to strain and misalignment is thereby eliminated. It's as simple as placing a round peg in a round hole.

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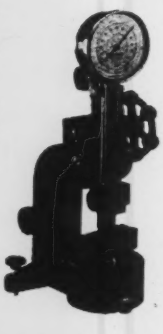

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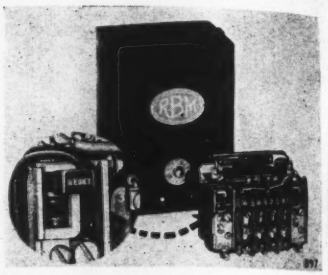
NEW INSTRUMENTS



visible palladium-silver snap-action contacts. Trip-free manual reset is standard; manual automatic reset is available at no extra charge.—*R-B-M Div., Essex Wire Corp., Logansport, Ind.*

Mention No. 483 when filling out card.

Tape Markers

New self-sticking cotton tape markers with plastic coating are mounted on handy dispenser cards. Available with color bands and symbols or lettering.—*Dept. 247, W. H. Brady Co., 160 E. Spring St., Chippewa Falls, Wis.*

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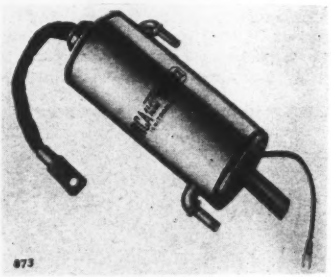
Ignitron

New "Type 5822" ignitron is water-cooled, steel-jacketed, mercury-pool-cathode tube for use in frequency-changer resistance-welding service, in



which 3-phase 60-cycle power is converted to single-phase power having a frequency of about 5 to 12 cps. Ignitor is suitable for intermittent operation.—*Tube Dept., Radio Corp. of America, Harrison, N. J.*

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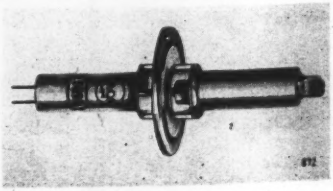
UHF Triode

New "Type 5893" medium-mu, "pencil-type" triode is for use in grounded-grid service as plate-pulsed oscillator at frequencies to 3300 Mc. With useful peak power output 1200 watts. Can



deliver 6 watts at 1000 Mc. as class-C r-f. power amplifier. Employs coaxial-electrode structure. Length is only 2-5/16 inches.—*Tube Dept., Radio Corp. of America, Harrison, N. J.*

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Special Cathode-ray Tubes

New special cathode-ray tubes include "Type K1052" 7-in. electrostatic tube containing five independent electron-gun and deflection-electrode structures, shielded to minimize interaction between channels. Another is "Type K1101P" 5-in. electrostatic tube for ultra-high-speed oscillography (up to 1000 Mc.), operated up to 37,000 volts. —*Allen B. DuMont Laboratories, Inc., 1000 Main Ave., Clifton, N. J.*

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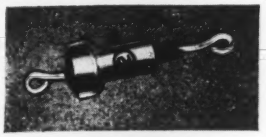
Feed-through Capacitor

New "Type 503C" small feed-through ceramic capacitor is resin-sealed in recessed cup at top of ferrule. Rated at



500 volts d.c.; capacitance ranges up to 100 uuf.—*Sprague Electric Co., North Adams, Mass.*

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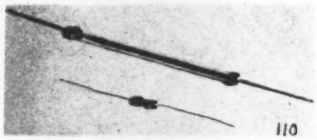
Selenium Rectifiers

New "Microstak" hermetically-sealed selenium rectifiers, with cell sizes down to 0.060-in. dia., are available in wide range of current and volt-



age ratings; are unaffected by humidity, dust, corrosive fumes, and changing pressures; are suitable for all electronic circuits.—*International Resistance Co., 401 N. Broad St., Phila. 8, Penna.*

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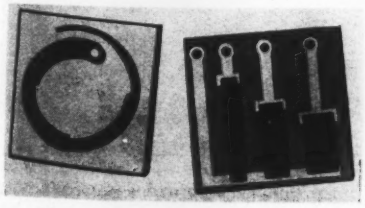
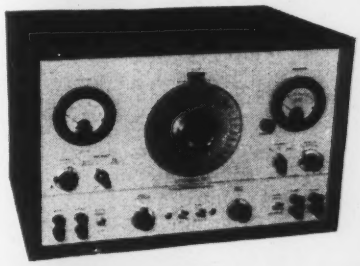
Printed Resistors

New printed resistors and resistance films of carbon composition type have from 25 ohms to one megohm per square. Wattage ratings are from 1 to 5 watts per sq. in. of film deposit, depending on heat-conducting characteristics of base material on which they



SERVOSCOPE®



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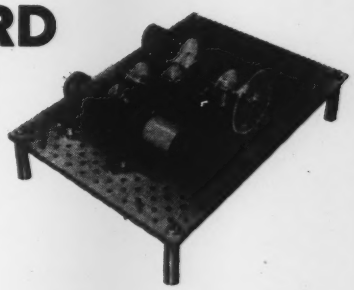

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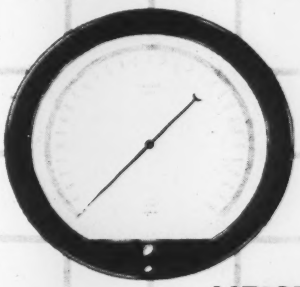

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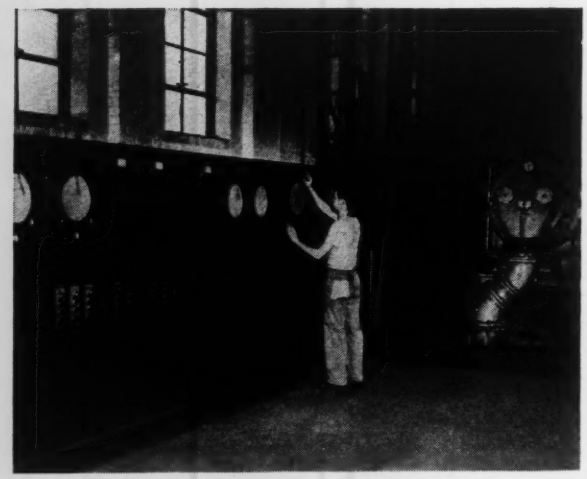
COORDINATION *of speeds, temperatures, pressures, flows and other variables . . . through modern instrumentation . . . makes possible the stabilization of continuous textile bleaching, and results in greater overall production in such a modern installation as this.*

From lab . . . to pilot plant . . .

Instruments



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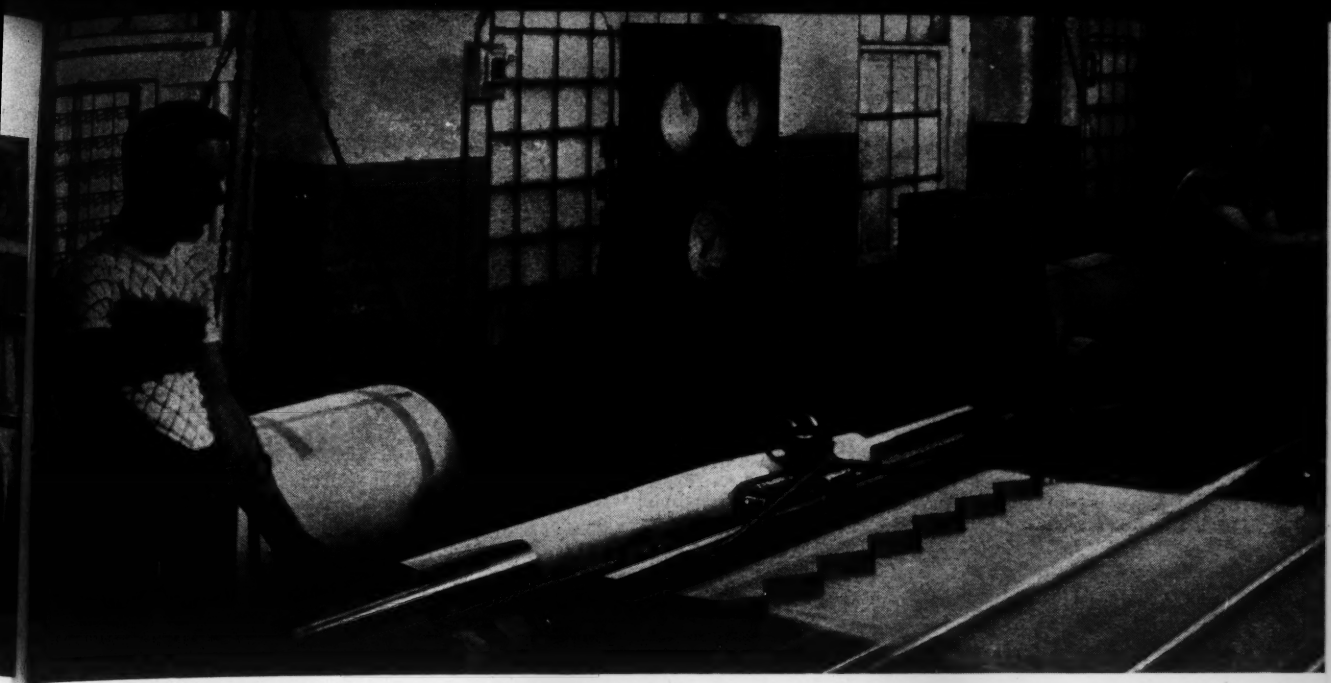

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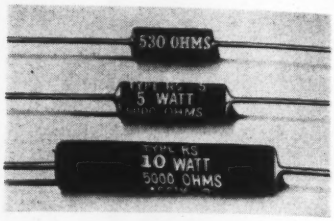

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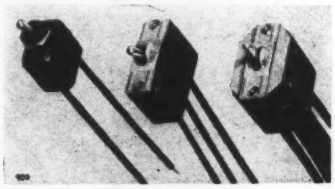

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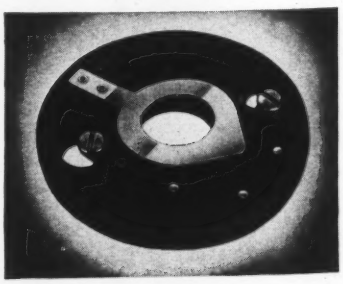

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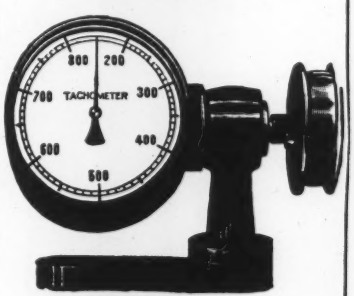

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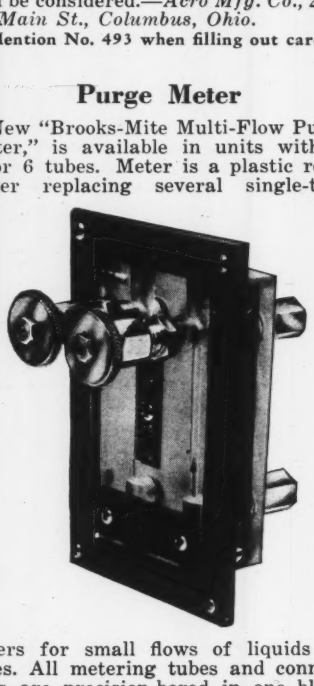

meters for small flows of liquids or gases. All metering tubes and connections are precision-bored in one block of acrylic plastic. Available with either a common manifold inlet for all tubes or individual inlets. Flow-rate adjustment is by needle-control valves for each tube.—*Dep't Y, Brooks Rotameter Co., Box 432, Lansdale, Penna.*

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Calendar of Important Instrumentation Events

1952

April 27-May 6
Heavy Industries Fair, Hanover, Germany. This fair includes exhibits of instruments for measurement, inspection, testing and control. For information write Deutsche Messe- und Ausstellungs-A.G., Hannover, Messegelaende, Germany.

May 2-3
Association for Computing Machinery, Spring meeting. For information write F. A. Schwertz, Mellon Institute of Industrial Research, University of Pittsburgh, Pittsburgh 13, Penna.

May 4-8
Electrochemical Society, Fiftieth Anniversary Meeting, Benjamin Franklin Hotel, Philadelphia. Sessions on Instrumentation have been scheduled. For information write Dr. Henry Linford, Sec., 235 West 102 St., New York 25.

May 5-16
British Industries Fair. Earls Court & Olympia, London includes laboratory and scientific instruments; Castle Bromwich, Birmingham, includes industrial instruments. For information write Board of Trade, Imperial Chemical House, London, S.W.1, England.

May 6-9
Scientific Apparatus Makers Association. Annual Meeting of all Sections. Edgewater Beach Hotel, Chicago.

May 7-9
Institute of Radio Engineers. National Conference on Airborne Electronics. Biltmore Hotel, Dayton, Ohio. For further information write E. K. Gannett, 1 East 79th St., New York 21.

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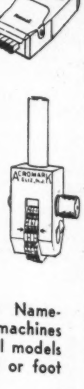

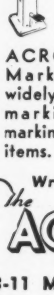

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May 13
American Association of Spectrographers Symposium "Instrumental Methods of Analysis in the Non-Ferrous Industry," Society of Western Engineers Building, 84 E. Randolph St., Chicago, Ill. For information write Robert Raisig, c/o Apex Smelting Co., 2537 W. Taylor St., Chicago 12, Ill.

May 14-16
Society for Experimental Stress Analysis, Spring meeting, Lincoln Hotel, Indianapolis, Ind. For information write V. H. McNeilly, 1207 Parkway Court, Lafayette, Ind.

May 16-17
Southwestern Institute of Radio Engineers. Conference and Radio Engineering Exhibit. Rice Hotel, Houston, Texas.

May 18-25
Achema X—Chemical Meeting and Exhibit, Frankfurt, Germany. At the same time and place the 25th International Congress for Industrial Chemistry will be held. Instruments will be exhibited. For information write Dr. H. Bretschneider, Deutsche Gesellschaft fuer Chemisches Apparatewisen, Frankfurt am Main 13, P.O. Box 1337, Germany.

May 22-23
"Electronics and Machines" Symposium, Professional Group on Industrial Electronics, Institute of Radio Engineers, Palmer House, Chicago. For information write Eugene Mittelmann, 549 W. Washington Blvd., Chicago 6, Ill.

May 22-24
American Society for Quality Control, Onondaga Memorial, Syracuse, N. Y. For information write W. R. Weaver, Gen. Chm., 1527 Republic Bldg., Cleveland 1, Ohio.

June 2-4
Symposium on Instrumentation for the Process Industries, School of Engineering, Chemical Engineering Dept., A & M College of Texas, College Station, Texas. For information write Dr. G. L. Farrar, Director.

June 11-13
American Congress on Surveying and Mapping. Twelfth Annual Meeting and Exhibit.
Shoreham Hotel, Washington, D. C.
For information write Walter S. Dix, Ex. Sec., P. O. Box 470, Benjamin Franklin Station, Washington 4, D. C.

June 19-21
ASME Applied Mechanics Division Symposium on Shock and Vibration Instrumentation, Pennsylvania State College, State College, Pa. For information write W. D. Kroll, Physicist, National Bureau of Standards, Washington 25, D.C.

June 23-27
ASTM 50th Anniversary Meeting and 10th Exhibit of Testing Apparatus and Laboratory Supplies, Hotel Statler, New York, N. Y. For information write Robert J. Painter, Asst. Sec., American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa.

Sept. 4-13
International Society of Photogrammetry, Shoreham Hotel, Washington D. C. For information write L. Ray Smart, U. S. Geological Survey, Trimetrogon Section, Washington 25, D. C.

Sept. 8-12
Instrument Society of America.
Seventh National Instrument Conference and Exhibit.
Public Auditorium, Cleveland, Ohio.

Sept. 22-30
Third Instruments and Measurements Conference and Exhibition, Stockholm, Sweden. For information write Mr. Yngve Axner, Kungl. Tekniska Hogspolan, Stockholm 70.

Sept. 29-Oct. 1
Eighth National Electronics Conference and Exhibition.
Sherman Hotel, Chicago.
For information write Karl Kramer, Ex. Sec., 852 E. 83rd St., Chicago 19.

October
Scientific Apparatus Makers Association.
Midyear Meeting of Recorder-Controller Section.
Seaview Country Club, Absecon, N. J.

Nov. 5-9
Scientific Apparatus Makers Association.
Midyear Meeting of Industrial Instrument, Laboratory Apparatus, Laboratory Equipment, Optical, Aeronautical, and Military Instruments Sections.
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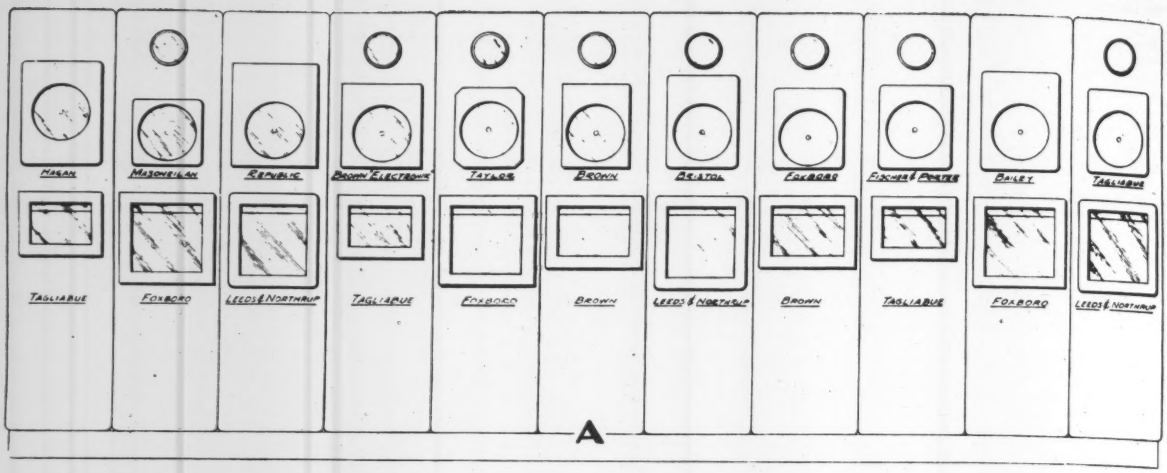


INSTRUMENT STANDARDIZATION

By L. G. KLINGENBERG, Principal Instrument Engineer and H. H. ELLIOTT, Senior Instrument Engineer
Chemical Plants Division, Blaw Knox Construction Company

INDUSTRIAL instruments have developed rapidly during the last 20 years. The result of this growth has been the elevation of the instrument industry to a high level in American technology. Unfortunately, standardization within this vital industry has not kept pace with its growth. As a result the instrument user faces many obstacles and delays when engineering the instrumentation for a plant.

Case Design

First, because of functional and aesthetic considerations, the selection of the supplier for the instruments that are mounted on the control boards and consoles is delayed until it has been determined which single vendor can best and most fully satisfy the requirements. With the existing hodgepodge of instrument-case sizes and designs, the instrument engineer usually refrains from mounting instruments of more than one supplier side by side on a control board. This point is illustrated in the figure, which shows "Control Board A" with instruments from many manufacturers mounted side by side, and "Control Board B" with instruments of identical case design mounted in a row. Thus the approach most often used in designing a control board now consists of specifying one manufacturer for all circular-chart instruments and the same or one other manufacturer for all strip-chart instruments. This method is at best a compromise which does not always produce the most satisfactory engineering job because it often discriminates against a superior instrument of one brand out of consideration for control-board uniformity and symmetry, which factors dictate the use of another manufacturer's instrument of this type.

There is no logical reason why the panel cut-out dimensions, front frame or bezel design, chart size, and chart position in the case, of all instruments in the same class (for example, the circular-chart type) could not be identical for all suppliers. As an example of what can be done along these lines, aircraft instruments have standard cases and mountings, making possible the interchangeability of various makes of instruments in the same instrument panel cut-out.

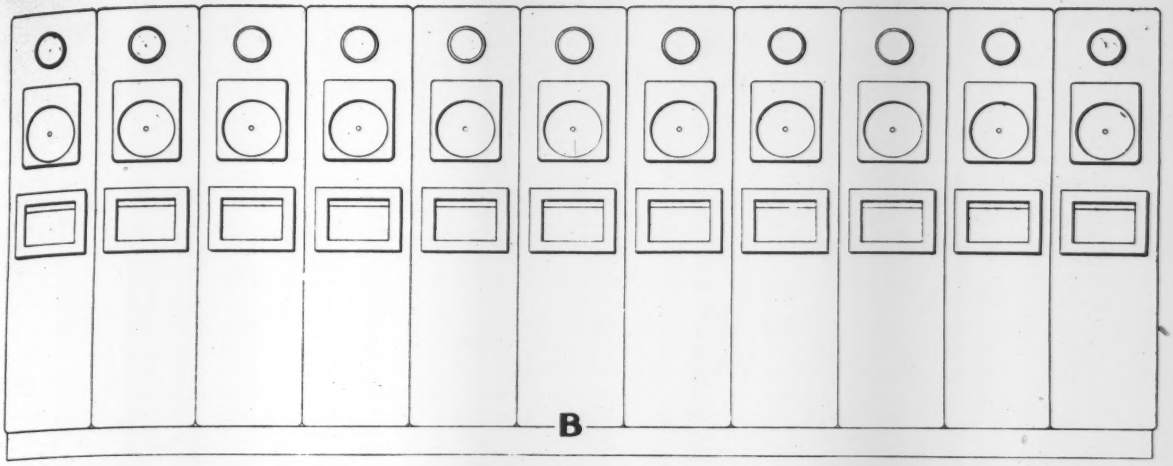
Certified Drawings

A delay that occurs when designing instrument control boards and consoles is the holdup of fabricating detail drawings due to delay in receiving certified vendor's drawings for all the instruments mounted on the panels. Specifications must be prepared, quotations obtained and analyzed, and purchase orders written before certified vendor's drawings can be obtained for these instruments. In an effort to prevent delays in the procurement of control boards, drawings for these items are usually issued with many dimensions marked with a "HOLD". These are not removed until vendors' drawings are finally secured, and the panel drawings revised and re-issued. Fabrication, of course, cannot proceed very far until the control-board fabricator receives a completed drawing without any "HOLD" on the construction details. This procedure is costly in time and money because it involves more engineering time, additional blue printing, and extra handling by the clerical and purchasing departments.

Another time-consuming delay is encountered when the process piping designer attempts to complete his piping details and finds he does not have certified drawings on equipment such as control valves, positive displacement meters, venturi tubes, and other items that constitute a piping system. This problem finally has been recognized by the control-valve manufacturers, who recently have agreed among themselves on standard face to face dimensions for control-valve bodies. A consequent reduction in piping drafting bottlenecks is anticipated because it no longer will be necessary to wait for certified vendors' drawings when all control valves are furnished in accordance with these standards. It will probably be a few years before these standards are adopted by the A. S. A., but at least it is a move in the right direction. However, the outlook is dim for standardization of positive displacement meters, venturi tubes, rotameters, and other instruments that are mounted in or on process piping and equipment because their inherent design characteristics do not lend themselves readily to standardization.

A Comprehensive Program

These delays, which are financially bad in peacetime, can be disastrous in critical times. Therefore, the manufacturers and users should resolve to carry out a comprehensive standardization program in the instrument industry. It is admitted that the benefits of such a program would not be realized for some time and would be of minor assistance to our current production of defense material. We must look into the future, however, because world af-



fairs indicate uncertain conditions for many years.

Although an instrument standardization program should cover all types of instruments, including laboratory, aircraft, inspection, and gaging instruments, this article discusses only the problems associated with industrial instruments of the types used for measuring and controlling process variables such as pressure, temperature, flow, and level; and mechanical quantities such as angular or linear motion, velocity, and acceleration. Also included in this category are the instruments for measurement and control of density, hydrogen-ion concentration, electrical conductivity, thermal conductivity, moisture content, composition, viscosity, humidity, nuclear radiation, etc.

The scope of instrument types mentioned covers such a wide variety of mechanical and electrical devices that standardization appears to present problems of almost infinite complexity. However, a large portion of this complexity should be regarded as the digressive outgrowth of a rapidly expanding industry suffering from the lack of standards, rather than as a reason why standardization could not be effected to the advantage of all concerned. Although the situation looks discouraging, a brief review of the situation brings out the following point in its favor. Most brands of instruments of similar types resemble each other closely in design and construction. For example, different makes of pressure-indicating gages of the same quality have but slight differences in construction, and the same is true for other common industrial instruments such as mechanically operated temperature and pressure recorders. Thus most of the industrial instruments of the type under consideration can be grouped into a relatively few types. As instruments in the same category have various features that could readily be standardized without suppressing new designs and developments, an important portion of a standardization program could be accomplished by concentrating early efforts along these lines. In the following paragraphs, some of these features are discussed.

Design Features

One of the first things that should be emphasized in a standardization program is the establishment of uniform instrument-case sizes and designs. This should include an agreement on the number of instrument-case sizes for each case shape, such as the circular case and the rectangular case. At the present time there is a great variety of case sizes and shapes for instruments. Accordingly, a minimum number of sizes should be established for each shape. For example, an ideal situation would be if the number of case sizes could be limited to three sizes for circular-case instruments and three sizes for the rectangular cases. As the visible parts on the front of the instruments are similar among most manufacturers, there is no reason why, with a little compromising among them, they could not all agree on standard designs for instrument cases. In addition to establishing standard case dimensions (except of course the depth of the case) features such as the location of the door hinge and other openings should be uniform among all manufacturers.

In addition to instrument-case design, there are several other design features of an instrument that require standardization. Some of these are; (1) Specific locations of fluid and electrical connections into the instrument case. These include the conduit connection for power to chart drives, balancing motors and switches, pressure impulse connections, and air-supply and air-loading connections. (2) Chart drives for circular-chart and miniature strip-chart recorders. This is one component of an instrument that should be absolutely interchangeable with all other makes of instruments of the same type. (3) Standardize the length of the pen arc radius and the location for the center of the pen arc radius for circular-chart recorders. This is almost a must for reasons discussed in the next paragraph.

One of the worst situations in the instrument industry today is the multiplicity of chart sizes, types, and ranges that operating companies must stock if they use instruments of more than one brand. This applies to both circular charts and strip charts. This situation could have been remedied easily by standardization years ago. Why should it be necessary to use different zero-to-ten uniformly-divided charts for various manufacturers' instruments simply because minor things such as the chart-drive hole diameter, the radiuse of the pen arc, the calibrated length of the pen arc, or the direction of rotation are different? Picture the chaotic condition that would exist in the motion-picture industry if each producer were to use a different film size or projection speed.

Performance Characteristics

In addition to physical design features, the performance characteristics of instruments should be standardized. The supply and output pressure ranges of pneumatic controllers and the transmission pressure ranges of pneumatic transmission system are examples of items in this category. For primary elements, the adoption of standard types and designs for numerous primary devices and their accessories such as thermocouple wire, resistance thermometers, thermowells, and orifice plates would be beneficial to the instrument industry.

Specifications

Instrument specifications, as well as physical features and performance characteristics, could be greatly improved by standardization. This would benefit all concerned by clarifying the intent and basic requirements represented by the specifications. The concept of a control valve coefficient (Cv) represents a noteworthy advance in standardization of specifications. For most applications, inspection of Cv values for different valves gives a direct indication of their relative capacities, and permits speedy calculation of actual capacities to a satisfactory degree of accuracy using standard equations. This has been of considerable value to the valve user because it usually permits direct calculations and com-

Continued on page 496

Stability *of* Controlled Processes

The factors of greatest importance in controlled-plant stability are (1) amplitude-frequency response and (2) phase change. An open-loop analysis of the system shows the effect of each.

By J. A. BARING
Askania Regulator Company

A PLANT under automatic control can be unstable. Instability, which causes the output of the plant to oscillate continuously, occurs when the sensitivity, or gain, of the regulator is increased beyond a certain critical value. The conditions which lead to instability can be within the plant, the regulator, and their interconnection. The dynamic behavior of a plant under automatic control can be investigated by using the concept of frequency response. This article presents a simplified and purely qualitative description of the frequency-response approach.

The Plant

Fig. 1A is a block diagram of a plant. The term "plant" refers to any apparatus whose output can be controlled by the variation of the input. In Fig. 1 the variable to be controlled (the output) is represented by the symbol W; the input is controlled by valve V.

The block marked "plant" represents all the internal characteristics of the plant. The block diagram is particularly useful because it illustrates the factor of primary importance—the relationship between the input and the output.

Fig. 1B shows a typical response of a plant when a step change in input is imposed. The step-function is one that is zero until a certain point, and then rises steeply to a new position at which it remains indefinitely. The response of the plant is an "S"-shaped curve. The time required for the output to reach final value is a function of the components comprising the plant—particularly the retarding effects (transportation lags and energy storage elements).

If the step input function is followed at some arbitrary later time by a step of equal height but opposite direction (Fig. 1C), the output (W_0) rises to a peak and then swings in the other direction.

If the input (V) is pulsed repeatedly, the output repeats its curve, as shown in Fig. 1C. Thus a periodic input produces a periodic output. The frequency of the output is the same as that of the input. However, the peaks do not coincide. If we consider the input peak to occur in the center of the impulse, then the peak of the output wave is delayed in time. Stated differently, the output *lags* the input. The lag often is represented by ϕ.

Fig. 2A shows the output if the input is a sine wave. The output again lags the input by a time interval. This time interval can be expressed in terms of *angle* of lag by dividing each cycle of the sine wave (T_1) into 360 degrees. The phase lag of the plant output behind the input now can be represented in degrees. This concept of angular measure as applied to a continuous wave is used commonly.

The height of the output wave can differ from that of the input wave. In Fig. 2A the input amplitude is designated as unity; the output (H_{p1}) is then a fraction of 1. As the frequency of a wave (F) is the number of cycles per second, and as the duration of one cycle (T) is the time for one cycle, therefore $F=1/T$.

The response of the plant to a sinoidal input of frequency F_1 is characterized by two quantities—(1) the phase lag, or angular displacement of the output behind the input, and (2) the ratio of the output amplitude to the input amplitude, in this case $H_{p1}/1$, or H_{p1}.

Fig. 2B shows a possible response of the plant to a new and higher frequency, F_2. The time for a full cycle (T_2) is less than T_1. The output again is characterized by two quantities—phase lag and amplitude. In general, at higher frequency the phase lag, (ϕ_{p2}) is larger than at frequency F_1, and the amplitude is smaller (except if resonance occurs).

The Regulator

Fig. 3 represents a regulator. The input signal to the regulator is the plant output (W_0). For simplicity, this regulator has an output (V') proportional to the change in W_0. This is *proportional control.*

As the regulator can have time delays and energy storages, it also can be described by a transient response similar to that shown for the plant—that is, by an "S"-shaped response to a step input. Similarly, if the input to the regulator is varied sinoidally, the output of the regulator also varies

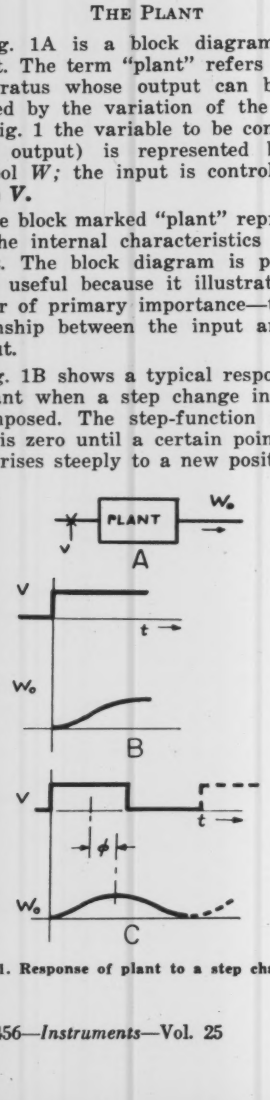


Fig. 1. Response of plant to a step change in input.

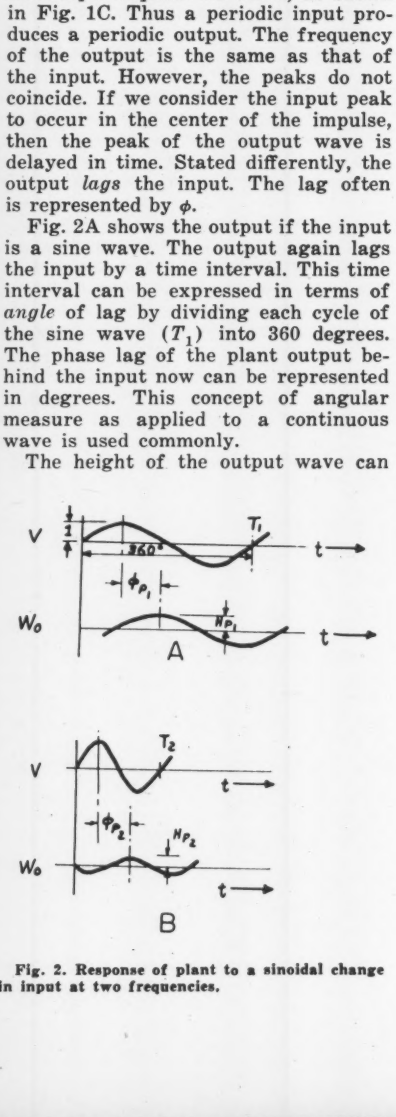


Fig. 2. Response of plant to a sinoidal change in input at two frequencies.

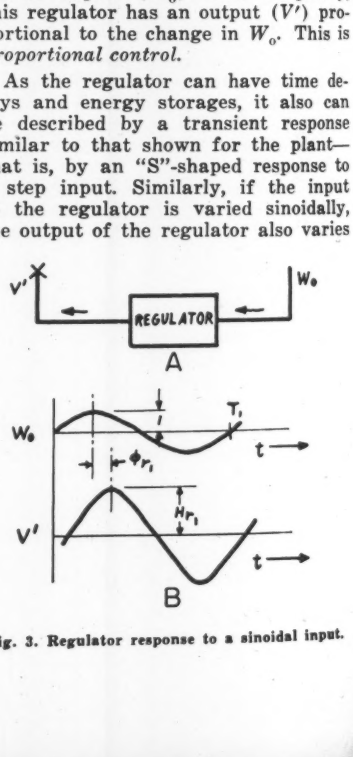


Fig. 3. Regulator response to a sinoidal input.

sinoidally at the same frequency. Thus the regulator response also can be characterized by a phase lag (ϕ_r) and an amplitude (H_r) as in Fig. 3B. Note that H_{r1}, the amplitude of the output at frequency F_1, is larger than the input. This condition can exist (without resonance) because a regulator has amplification and an external source of power. When the sensitivity, or gain, of the regulator is increased, H_r increases in proportion because of proportional control, and can be larger than the input.

In Fig. 4A the plant output is connected to the regulator. Note that the output of the regulator (V') is *not*

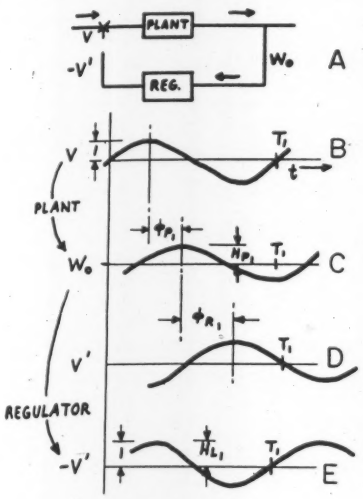


Fig. 4. Plant and regulator response to a sinoidal input.

connected to the valve. The input to the regulator is the output of the plant. By expressing the behavior of V' in terms of V, we have the *open-loop response* of the complete system. This loop response is fundamental in consideration of stability.

Suppose that we vary the input to the plant by varying valve V at any arbitrary frequency (F_1) and with unity amplitude, as in Fig. 4B. The output of the plant is a sine wave lagging by ϕ_{p1} and with amplitude H_{p1} (curve C). As the regulator input is the plant output, the same curve (W_o) is the input to the regulator.

The regulator output (V') is shown in Fig. 4D. It also is a sine wave that lags W_o by angle ϕ_{R1}, and with an amplitude equal to H_{p1} times H_{R1}. Curve E is simply the inverted curve D—that is, it is minus V'. Curve E is the one normally fed back to the valve V from the regulator. The inversion of this curve follows from the fact that the output of the regulator must be negative if it is to compensate for changes in W_o; if the plant output increases, the regulator causes a decrease in the output. Thus, the regulator is designed with 180-degree phase lag—beyond that caused by the retarding effects in the regulator components themselves.

The total *open-loop phase lag*—that is, the lag from V to V' in Fig. 4A, is equal to the sum of the lags in the plant and regulator, plus 180 degrees:

$$\phi_L = \phi_P + \phi_R + 180°$$

The *open-loop gain*, H_L, or V'/V, is equal to the product of the gains in the plant and the regulator:

$$H_L = H_P \times H_R.$$

Now compare the input variation originally applied to valve V with the resulting output variation from the regulator. We have tested our system at an arbitrary frequency, F_1. Note that with the particular lags chosen

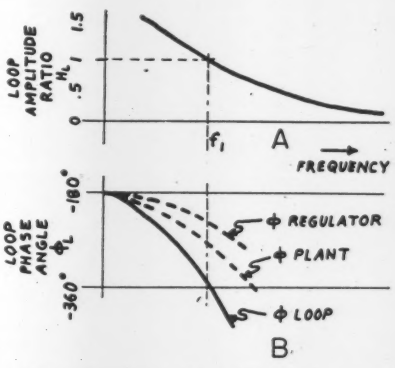


Fig. 5. Regulator and plant open-loop response curves. A, ratio of regulator output to plant input versus frequency; B, phase lags of plant and regulator vs. frequency.

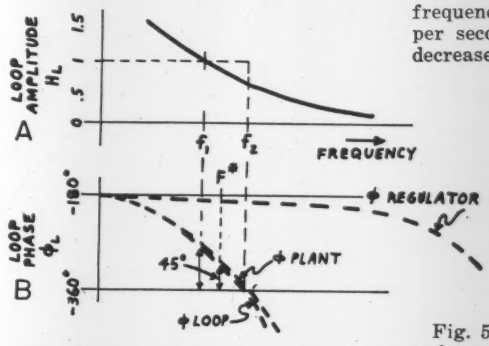


Fig. 6. Phase lag of regulator and plant with a high-performance regulator.

in this example, V' happens to be identical to V in amplitude, phase, and (of course) frequency. This was done to illustrate a point. The amplitude is identical because the regular sensitivity was adjusted to the point where $H_{L1} = 1$, the input amplitude. The phase is identical because the total phase lag is 360 degrees. The frequency is identical because a linear system cannot alter the input frequency.

If we connect V' to V in Fig. 4, we no longer have to vary V externally. With the two connected, the system continues to oscillate. We have instability, or hunting. As soon as we connect V and V', any random disturbance which moves any part of the regulator or plant causes the system to break into oscillation.

Summing up, the energy storage elements and delays within the plant and the regulator have caused a 180-degree phase lag between the input and the output at our arbitrary test frequency. As the regulator is designed to provide an additional lag of 180 degrees, the total is 360 degrees, or one full cycle. The regulator output can now supply the input with the same signal—*provided its sensitivity is high enough to give unity (or greater) loop gain.* The plant and regulator combination will continue to oscillate sinoidally without any assistance from the outside; we have instability. Note that the plant and regulator are considered together in this analysis.

Stability Criterion

We can now establish the general criterion for stability: *If, at the frequency at which the phase lag around the open-loop is* 360 *degrees, the loop gain* (H_L) *is less than* 1, *the system is stable.*

We have talked only about the response of the plant at one test frequency. In order to test for stability, we must check the loop phase shift *at all frequencies.* When we find the frequency at which the 360-degree lag occurs (and there always is one) we then must check the amplitude at that frequency to see that it is less than unity. The procedure is illustrated in Fig. 5. The amplitude and the phase around the open loop of plant and regulator are checked and plotted at all frequencies from zero to several cycles per second. In general, the amplitude decreases as frequency increases. Also, the phase usually starts at minus 180 degrees at low frequency (because of regulator action) and approaches minus 360 degrees as the frequency is increased. At the point where the phase curve crosses minus 360 degrees we must check the amplitude curve. If it is greater than (or equal to) unity, our system is unstable.

Fig. 5 is the plot made for the plant and regulator described in Fig. 4. At the arbitrary frequency, F_1, the amplitude equals unity. Thus the system is unstable.

The log of the loop amplitude ratio (Fig. 5A) often is plotted rather than the ratio itself. This is convenient because the gains of the plant, regulator, etc., can be added to find the total loop gain. The familiar decibel notation is used—that is, the amplitude ratio in db. is:

$$\text{Db.} = 20 \log_{10} V'/V.$$

Fig. 6 shows the frequency response curve for the same plant with a different regulator. The phase lag of this regulator is small in the frequency region of interest. Thus the total phase lag in the low-frequency region is not large. The gain of unity at F_1 no longer causes instability. The critical

Continued on page 494

Vacuum-tube Electrometer Applications

This familiar research tool of the physicist can have many uses for the industrial instrument engineer who knows its features, limitations, and applications.

By JOSEPH F. KEITHLEY
Keithley Instruments

ELECTROMETERS are sensitive potential-measuring instruments with growing usefulness in both research and engineering. Their outstanding characteristic is a very high input-impedance, permitting measurements of potential sources while drawing small current. Original electrometers were based on measurements of the electrostatic forces associated with charges; the Lindemann Electrometer and the common Electrostatic Voltmeter are two modern instruments which use this principle. The vacuum-tube electrometer is a vacuum-tube voltmeter with special provisions for attaining high input-impedance.

Impedance

The impedance of any device is the ratio of the voltage applied across the device to the current that flows through the device. Thus a device that measures a voltage without drawing *any* current has infinite impedance. When a signal is applied to the grid of a vacuum tube, the grid unfortunately draws some current. In the vacuum-tube electrometer, special precautions are taken to minimize this grid current (that is, to keep the input impedance high.)

Vacuum tubes are used for many electrometer (high-impedance) applications. The unknown voltage is applied to the grid; the change in plate current is used as an index of the grid voltage. The grid current of the electrometer tube is kept low by using (1) a good vacuum in the envelope, (2) low electrode potentials to minimize gas ionization, (3) low cathode-emission current, and (4) proper grid potentials to assure that all cathode emission goes to the plate. The tube is operated in darkness to minimize photo emission from the grid, and the glass envelope is treated to keep its resistance high. With these precautions, the grid current can be kept as low as 10^{-17} ampere. Tubes with grid currents of 10^{-14} ampere and higher, however, are adequate for many applications.

Advantages and Features

The vacuum-tube electrometer has two outstanding advantages. First is the low input capacitance, permitting shorter time constants in high-resistance circuits, and the capacitance remains constant with varying input voltages. Second is the elimination of long-period oscillations resulting from the mass and low restoring torque of a sensitive torsional system. Only a relatively insensitive panel meter is required, permitting a portable instrument.

A principal use of electrometer tubes at present is in radiation-measuring equipment. Ion current caused by the radiation is passed through a high resistance in the grid circuit of the electrometer tube. The resistance is selected so that the ion current produces about one volt drop; currents approximately the magnitude of the tube grid current and larger can be measured in this fashion.

Special subminiature tubes with 1.5-volt 10-milliampere filaments are being produced for portable equipment. These tubes have grid currents of about 10^{-14} ampere, a g_m of approximately 100 micromhos, and a mu of 2. The Victoreen Instrument Co. "Type 5803" is a typical electrometer tube.

A tube with such low grid current has many general uses for the electrical engineer, in addition to the specialized field of radiation measurement. Its small size and low filament power allow the design of a convenient voltmeter which is small, lightweight, and economical.

A simplified circuit diagram of a vacuum-tube electrometer is shown in Fig. 1. Degeneration is used to improve stability and linearity and to permit large grid signals. R_1 is a one-megohm resistor that protects the tube by limiting grid currents when excessive positive voltage is applied to the HI terminal. It also limits the current drawn from low-impedance sources when the input switch is closed for setting the zero. R_2 provides zero stability as the filament battery discharges; by its use the zero drift of the instrument is held to about 0.002 volt per hour on a 2-volt scale and about 0.02 volt per hour on a 20-volt scale with the input terminals connected together. R_4 is the calibration adjustment, and R_5 the zero control. A range switch disconnects all batteries in the OFF position and connects a different set of resistors (except R_1) and battery potentials in the circuit for each range.

The HI terminal, input switch, and R_1 are well insulated with polystyrene, giving an input resistance greater than 10^{14} ohms; the input capacitance is approximately 6 uuf.

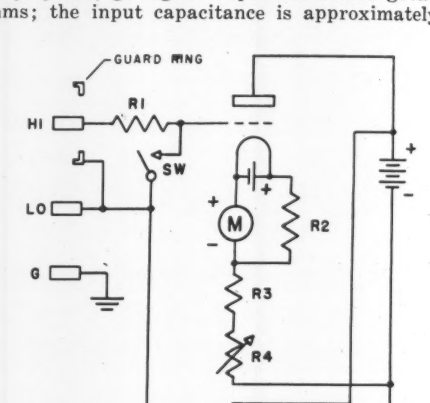


Fig. 1. Simplified circuit diagram.

Grid currents are less than 5×10^{-14} ampere with 2-volt range and 5×10^{-13} ampere on the 20-volt range.

The electrometer has characteristics that surprise those accustomed only to ordinary voltmeters. When a battery is connected to the input, the electrometer reads the voltage correctly, and it continues to read it after the battery is disconnected from the instrument. This is because the 6-uuf. input capacity is charged and the input resistance is so high that it remains charged. The electrometer is so sensitive that large meter deflections can be produced by waving a charged comb ten feet away.

When the electrometer is running open circuited, the grid current in the tube, which is produced by ionization and secondary emission, charges the input capacitance. This causes the meter pointer to drift slowly across the scale in about three minutes. Thus the grid current of approximately 5×10^{-14} ampere is the limiting factor in the use of the electrometer; it sends spurious currents through the circuits being measured and obscures smaller currents.

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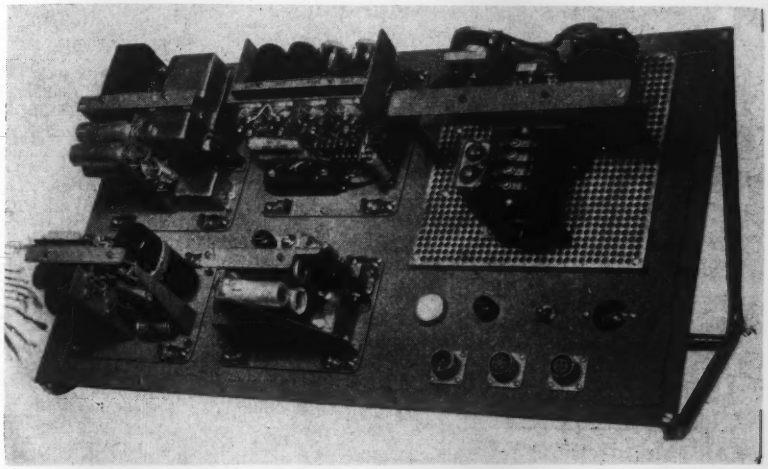
The Electromechanical Servomechanism in Process Control

By P. H. WILLIAMS
Servomechanisms, Inc.



High-sensitivity, single-positional servomechanism subdivided into plug-in units and mounted on a sloping panel for ready accessibility. Units have cover removed to show compactness of internal construction. Three electrical connectors provide for supplying power to the system as well as for introducing a command transducer signal and extracting the output intelligence data.

PRECISION process-control systems can be made to perform any number of simultaneous control operations when suitably interconnected, and with high accuracy and reliability. A transition is occurring in all fields of industrial control, such as mixing, filtering, shaping, extruding, rolling, and cutting. Although techniques now in use represent a vast advance over earlier methods, the economic pressure for better things at lower costs is spurring industry to look for new methods of control and indication. For example, the control problem of the long-time-constant process is being solved by use of servomechanisms of all types.

Development work during World War II raised the electromechanical servomechanism to a high degree of performance. The servomechanism is a simple electromechanical device capable, when used in conjunction with suitable detecting instruments, of controlling important variables in industrial processes. Many control devices for future industrial control systems will consist of analog computers and interrelated servomechanisms, perhaps augmented by auxiliary timing and switching apparatus. Such devices are a reality now, and the general principles can be expected to remain unchanged. Further engineering advances will be concentrated in the field of improved dynamic frequency response, static accuracy, and increased reliability and service life.

The construction of a simple servo or servo analog computer for a specific application is becoming a building-block operation. The fundamental servo components are mounted in convenient locations and interconnected by electrical wiring to form a complete control system. Where it is convenient to have the entire system in one location, the components can be assembled on a flat mounting plate or relay rack unit by plug-in method. Where space is at a premium, the components can be distributed in available compartments or cabinets and interconnected by electrical cables which plug into the various units. Where it is necessary to have great separation of components, telemetering techniques permit high-performance servo operation even though the components are widely separated.

The plug-in feature of basic functional packages is essential. It reduces maintenance to one simple operation—replacing a unit simply by unplugging it from its location on the mounting plate and plugging the new unit into the receptacle. The "down time" of the machine or process being controlled by the servomechanism is thus low, and can be reduced to zero by having a stand-by servo system automatically switched into operation when the operating servo system fails to perform properly. A pilot light can indicate to a human monitor on duty at a central factory observation station that this "switchover" has occurred; the monitor would then replace the faulty plug-in unit.

Servosystem Components

The building-block components required to build a single basic servomechanism are: (1) a servoamplifier, (2) a power supply, (3) a mechanism, and (4) an adapter. More than one of each may be used for more elaborate problems.

The *amplifier*, energized by the *power supply*, drives a servomotor contained in the mechanism according to an electrical input command signal. All the rotating electrical and mechanical computing components, together with their inter-gearing, are contained in the *mechanism*. The output of the mechanism is either a rotating shaft which actuates the device to be controlled, and/or one or more electrical control signals from rotating electrical elements. The *adapter* contains the specialized calibrating and scaling circuitry required to adapt the generalized components to specific applications. One adapter can serve a system composed of several mechanisms, amplifiers, and power supplies.

Servomechanism Types

There are two general servomechanism categories—the *shaft-positioning servo* and the *shaft-velocity servo*. In the first, a change in the input electrical command signal causes the rotating components in the mechanism to execute a corresponding change in their angular position. In the second, the input commands control the rotational *velocity* of the rotating components. These two types of "servo loops" can be combined and interconnected in any quantity to form elaborate control systems which can use mechanical and electrical analogs of variable quantities to perform almost any mathematical operation required in the control problem and to produce the necessary output to actuate the controlled equipment. Auxiliary apparatus can be incorporated in the system to analyze responses, to perform several mathematical operations, and to remotely display and record the

Continued on page 492

INSTRUMENT ELECTRONICS

The amplifier is a basic electron-tube circuit. Important amplifier factors include classification, distortion, coupling, video amplifiers, bias methods, feedback, cathode followers, electrometer tubes, and noise level. The first three factors were presented last month. The other six factors are presented in this installment.

By MILTON H. ARONSON
Technical Editor, *Instruments*

VIII. AMPLIFIER CIRCUITS (*Continued*)

Video Amplifiers

A video amplifier usually is an RC-coupled amplifier with special provisions for widening the response band—that is, for making the stage amplify uniformly a wide band of frequencies (from almost zero to several megacycles). This is done by using *compensation* to overcome the drop in response at low and high frequencies.

Low-frequency Compensation

The loss of gain at low frequency can be remedied by a low-frequency compensation filter in series with the load resistor (Fig. 8-11). This compensation circuit consists of two elements, a capacitor C_f and a resistor R_f. The purpose of this network in series with the plate-load resistor R_l is twofold. First, it introduces a phase shift in the plate circuit that compensates for the phase shift in the coupling circuit R_gC_c. Second, it increases the plate load impedance at low frequencies, thus maintaining the gain.

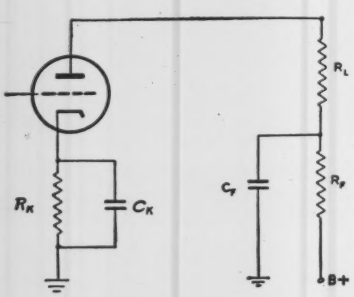


Fig. 8-11. Low-frequency compensation.

High-frequency Compensation.

The loss of gain of an amplifier stage at high frequencies is caused by the shunting action of interelectrode and distributed capacities. The effect of these capacities can be overcome by adding small inductors in the plate circuit, as shown in Fig. 8-12. The *shunt-compensation* coil L_1 boosts the response at high frequencies by increasing the plate impedance (the reactance of a coil increases with frequency). The series-compensation coil L_2, in series with the grid of the second stage, resonates with the input capacitance of the second stage. This increases the gain near the resonant frequency.

High and low compensation is used in oscilloscope, radar, and television video amplifiers so that pulse-type signals with components from zero to 4 megacycles can be amplified without excessive distortion.

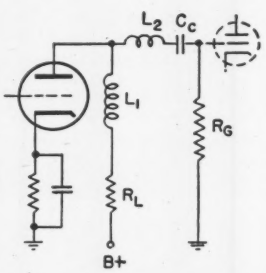


Fig. 8-12. High-frequency compensation.

Methods of Obtaining Bias

Fixed Bias

There are three general methods of providing bias voltage. In one method, bias is obtained from a source of voltage especially provided for the purpose, such as a battery or a low-voltage d-c. power supply. This method, known as *fixed bias*, is illustrated in Fig. 8-1. It has the advantage of providing a constant bias, but the disadvantage of requiring a separate source.

Cathode Bias

The second biasing method is a resistor in the cathode circuit, as shown in Figs. 8-11 and 8-12. The plate current flowing through the cathode resistor produces a voltage drop across it. The cathode of the tube is thus positive with respect to ground by this *IR* drop. As the grid usually is at ground potential, it is negative with respect to the cathode by the amount of *IR* drop across the cathode resistor. This method, known as *cathode bias*, is the most common method for obtaining bias because it requires only a resistor and a shunting capacitor. As the bias voltage depends on the flow of plate current, the tube cannot be cut off by means of cathode bias developed across a cathode resistor.

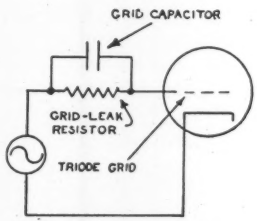


Fig. 8-13. Grid-leak bias.

The capacitor shunted across the cathode resistor provides a low-impedance path to ground for the a-c. signal. The capacitor offers negligible reactance to the input signal—that is, it appears as a short circuit to the signal voltage. As only the d-c. component of the plate current flows through the resistor, the d-c. bias voltage is unaffected by the signal and remains constant. The value of the capacitor depends on the value of the resistor and on the frequency that is being amplified. The reactance of the capacitor should be less than one-tenth the resistance of the resistor at the lowest frequency to be amplified. It will be even less at higher frequencies, of course.

Grid-leak Bias

The third method of providing a biasing voltage, called *grid-leak bias*, is illustrated in Fig. 8-13. During the time when the input signal drives the grid positive with respect to the cathode, electrons flow from the cathode to the grid.

ANSWERS TO QUIZ VIII.—AMPLIFIER CIRCUITS (Part 1)

8-1.	(a)	8-6.	(c)	8-10.	(c)	8-15.	(a)	8-19.	(b)
8-2.	(c)	8-7.	(c)	8-11.	(d)	8-16.	(a)	8-20.	(c)
8-3.	(b)	8-8.	(d)	8-12.	(a)	8-17.	(a)	8-21.	(d)
8-4.	(a)	8-9.	(c)	8-13.	(c)	8-18.	(c)	8-22.	(a)
8-5.	(b)			8-14.	(c)			8-23.	(c)

Test items for VIII. (Part II)—Page 504

These electrons neutralize the positive grid, hold it at zero potential, and charge the grid capacitor to the full value of the positive input voltage.

During the negative swing of the input signal, no grid current flows. The electrons on the grid capacitor then can discharge—but only through the grid-leak resistor, which has a value on the order of 500,000 ohms. If the discharge time-constant for the capacitor is long in comparison with the period of the input signal, only a small part of the charge on the capacitor is lost before the next positive portion of the input signal arrives. Thus, the grid side of the capacitor stays negative until the next positive half cycle of the input signal. The bias voltage developed across the resistor by the charging of the capacitor is fairly constant, and the instantaneous grid voltage follows the input signal above and below this average negative bias voltage.

When using grid-leak bias, a precaution must sometimes be taken to prevent the tube from burning out. The bias depends on a signal voltage and, therefore, if no signal reaches the grid the plate current can increase and burn out the tube. In transmitter circuits a fixed bias generally is used in conjunction with grid-leak bias so that the tubes can not burn up if there is no driving signal.

Feedback

Feedback refers to the process of transferring energy from the output of a circuit to its input (Fig. 8-14). There

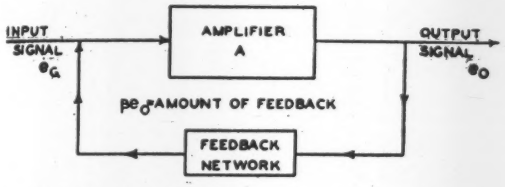


Fig. 8-14. Feedback principle showing how a fraction (β) of the output is fed back into the input.

are two types of feedback—(1) *regenerative*, or positive, feedback and (2) *degenerative*, or negative, feedback. Negative feedback also is called *inverse* feedback.

If the signal feedback is 180 degrees out of phase with the input signal, it subtracts from the input and reduces the gain. This is negative feedback.

If the signal feedback is in phase with the input signal, it adds to it and increases the gain of the amplifier. As increasing the gain means a bigger signal, which in turn causes still more gain, positive feedback causes the circuit to be unstable and to *oscillate*. This is the principle of oscillation.

Negative feedback is used commonly because it reduces distortion introduced by the amplifier. For example, if the amplifier increases only one portion of a signal that appears at the input, this increased portion (when fed back to the input) acts to decrease the gain of the stage for that portion of the signal, thus re-establishing linearity. Similarly, amplitude distortion and noise *generated inside* the circuit around which feedback occurs are reduced by negative feedback. In effect, negative feedback first reduces the gain of an amplifier and then automatically raises or lowers the gain to maintain amplitude linearity.

Feedback can be done in many ways, simply by taking a portion of the output of any circuit and coupling it back into the input. One common method of obtaining negative feedback around one stage only is to use an unbypassed cathode resistor, as shown in Fig. 8-15. When the input signal is positive, more current flows. This current causes the cathode to go positive, thus *reducing* the grid-cathode potential—which is the effective signal voltage. This type negative feedback is called current feedback because the plate current causes it. The signal voltage developed across the cathode resistor is effectively the "feedback" signal. Note that the only difference between a cathode resistor used for degeneration (negative feedback) and one used for cathode bias is that the latter bypasses the signal voltage

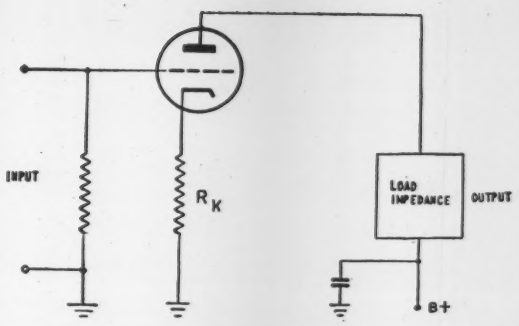


Fig. 8-15. Current feedback.

by a capacitor. The former provides both cathode bias and signal degeneration.

The Cathode Follower

The cathode follower, or current follower, is used commonly in industrial electronic instruments because of its high input impedance and low output impedance.

A conventional cathode follower is shown in Fig. 8-16. It is a single-stage inverse-feedback circuit in which the output voltage is taken across the cathode resistor. The plate

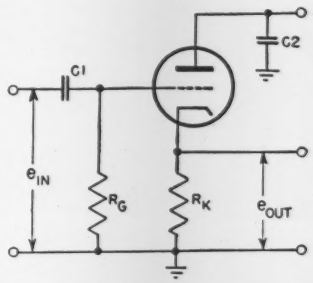


Fig. 8-16. Cathode follower.

is tied directly to B+. Thus, if a positive signal is applied to the grid, the rise in plate current through R_k produces a greater i_pR_k drop, making the cathode more positive. Likewise, a negative signal applied to the grid causes a decrease in the i_pR_k drop, making the cathode less positive. Thus, the voltage across the cathode resistor "follows" the grid, which in effect reduces the voltage difference between grid and cathode as established by the input signal.

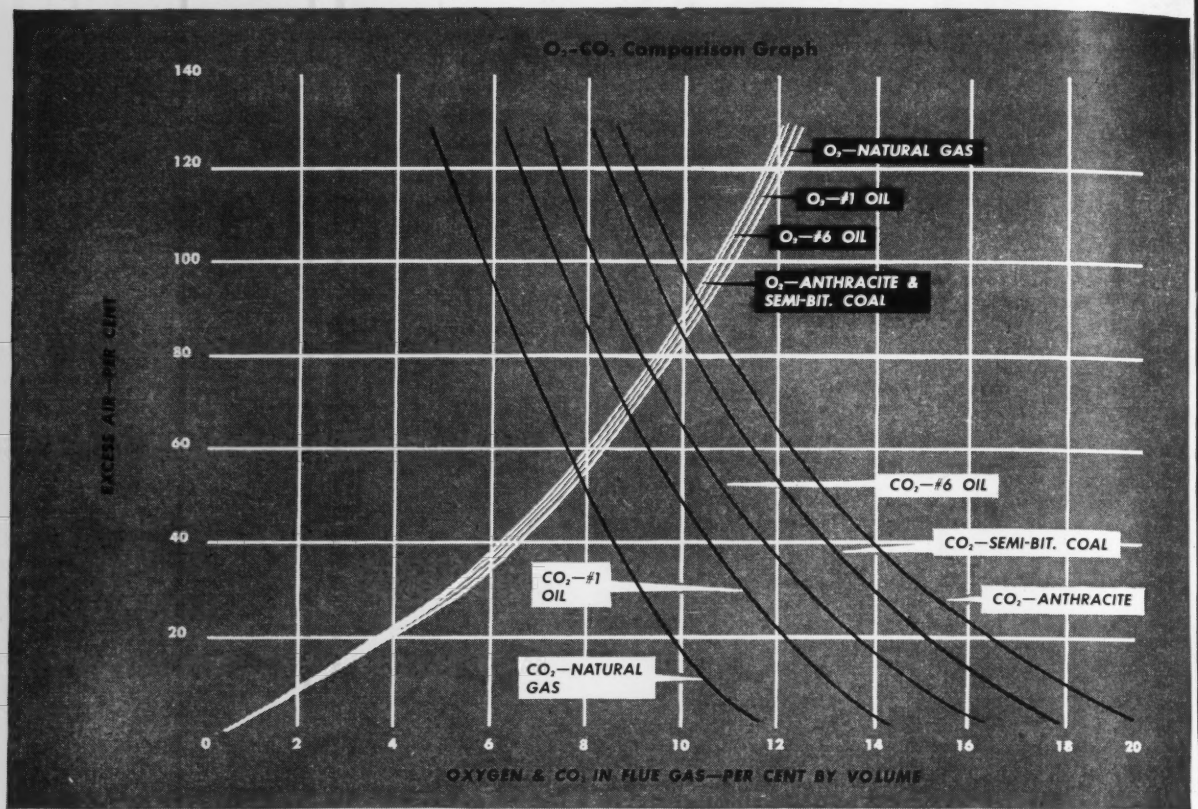
If no signal is applied to the grid, there is a certain amount of plate current flowing through R_k. The resulting i_pR_k drop establishes the no-signal bias developed across the resistance. The signal variation on the grid produces a plate-current variation through the cathode resistor, which causes the cathode potential to "follow" the grid potential. Thus, the instantaneous grid bias, which is the grid-cathode potential, does not change much. This is in contrast to the operation of a conventional amplifier in which the grid-cathode potential changes exactly as the input signal. As the grid-cathode potential of a cathode follower does not change much when an input signal is applied to the grid, the cathode follower has high input impedance and can handle large positive and negative signals with distortion, as will be described.

Voltage Gain

A positive signal applied to the grid of an electron tube causes an increase in plate current. In the cathode follower, the increased plate current causes the cathode potential to rise. This, in effect reduces the grid-cathode potential, which is the potential that controls the plate current. If the cathode potential were to change by a greater amount than the grid potential, the effect would be to *reduce* plate current because a positive change in cathode potential is

Continued on page 498

How to burn Multiple Fuels efficiently



Oxygen and Oxygen alone gives you an undistorted picture of the amount of excess air present.

When switching from one fuel to another or burning more than one fuel at the same time, you can realize large savings with a continuous indication of Oxygen content in your flue gas—because Oxygen and Oxygen alone gives you an undistorted picture of the amount of excess air present.

This fact is borne out by the graph showing the relationship of excess air to CO_2 and O_2 in the flue gas of five common fuels. While the O_2 curves nearly coincide (especially in the important 30% excess air range) the CO_2 curves diverge widely.

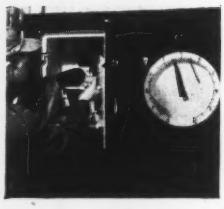
Large Savings Possible

This deviation was costing a medium sized refinery in Michigan $35-40 per day in boiler room fuel costs. Burning a combination of oil and gas they found that a combustion control system to handle their multiple fuel firing conditions would cost more than their small boilers.

They purchased a Hays Magno-Therm Oxygen Recorder, and immediately found that their boiler operation was so inefficient that the pen would not stay on the 0-10% chart. However, by operating with reference to the O_2 recorder they were able to reduce fuel costs enough *to pay for the instrument in 40 days.*

With the Hays Magno-Therm Oxygen Recorder you get:

Continuous, highly accurate indication and recording.
Complete compensation for temperature and pressure effects.
Freedom from chemicals or hazardous fuel burning in the analyzing process.
Swift, sure electronic operation.



If you are facing the problem of multiple fuel combustion, you will want a detailed copy of this O_2-CO_2 Comparison Graph as well as Hays Bulletin 50-829—describing the Magno-Therm Oxygen Recorder. Write for this free information.

THE HAYS CORPORATION
MICHIGAN CITY 8, INDIANA

Automatic Combustion Control • Boiler Panels • Hays-Penn Flowmeters
Veriflow Meters and Veritrol • Gas Analyzers • Draft Gages
Combustion Test Sets • CO_2 Recorders • Electronic Oxygen Recorders

INSTRUMENT SOCIETY of AMERICA Journal

Vol. 8 APRIL 1952 No. 4

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THE MANAGER'S CORNER

Percy V. Jones

It gives us great pleasure this month to bring to the membership the report of ISA Treasurer George R. Feeley. This simplified financial report with its accompanying illustrations follows a pattern that has come into general usage by large industries in reporting to their stockholders. Mr. Feeley has done a fine job of clearly explaining to the many of us who are not accountants the financial status of the National Society.

G. R. FEELEY

We also call your particular attention to the report of Chairman W. H. Brand of the Committee on Instrumentation for Production Processes, which shows that the Technical Program for the 7th National Instrument Conference and Exhibit is well underway and will better the best to date.

Treasurer's Report

Recent actions of the ISA Council and Executive Board have brought about a great deal of discussion of Society Finances. The following report for the year 1951 may serve to answer some of the questions that have been raised.

First let us look at a summary of the Audit Report:

Statement of Condition
December 31, 1951

We Have:	
Cash on Hand and in Banks	$45,925.93
Investments & Special Interest Accounts	30,000.00
Other Assets (Furniture, Insignia, supplies, etc.)	11,989.51
Total Assets	$87,915.44
We Owe:	
Deposits on 1952 exhibit	$13,759.24
Due Sections (Dues Refunds)	750.00
Taxes Withheld (Employees)	721.18
Reserves for depreciation etc.	5,478.83
Total Liabilities	$20,709.25
Surplus:	
January 1, 1951	$52,748.57
1951 Net Income	14,457.62
December 31, 1951	$67,206.19
Total Liabilities & Surplus	$87,915.44

Statement of Income & Expenses
January 1 to December 31, 1951

We received from:	
Dues & Membership Activities	$ 53,069.61
Annual Conference	7,046.09
Exhibit	70,493.00
I.S.A. Journal	1,276.23
Gov't Bonds (Interest)	250.00
Miscellaneous Sources	215.55
	$132,350.48
We spent for:	
Section Refunds & Membership Activities	$ 39,308.25
Annual Conference	16,184.98
Exhibit	39,669.34
Operation of Nat'l Hdqts	21,713.94
Officers & Committees & Professional Services	1,016.35
	$117,892.86
As a result of the years operation, we have added to surplus	$ 14,457.62

An informative analysis of current receipts and disbursements can be made on the basis of the "Income Dollar" and how it was used. Let us look at a breakdown of where our money comes from and where it goes (see illustrations on facing page).

Another interesting analysis of expenses can be made on the basis of cost per member of the various society activities. Based on the average membership for the year 1951, the society expense per member excluding Instrument Exhibit can be broken down as follows:

Activity	*Cost per member*
Subscription to Instruments Magazine	$1.50
Recommended practices & Binders	.53
Conference (based on net cost)	1.98
Operation of National Headquarters	4.72
Administration and Professional Services	.22
Total cost per member	$8.95
Dues Income per regular member (Amount retained by Nat'l Office)	5.00
Expense per member beyond dues income	$3.95

The above analysis indicates very clearly the fact that the Society is dependent on a source of income other than membership dues. The stability of our present position is the result of the financial success of our past Instrument Exhibits.

GEORGE R. FEELEY
Treasurer

Tentative Recommended Practice Distributed

The Tentative Recommended Practice on Mercury Handling, RP11.1, prepared by the ISA Sub-Committee on Mercury Handling, under the Chairmanship of A. V. Novak, E. I. duPont de Nemours & Co., Inc. is now being distributed to the Members of the Society.

This Recommended Practice has been prepared as part of the service of the Instrument Society of America toward a goal of uniformity in the field of Instrumentation.

The purpose of this particular report is to provide a safe and practical guide to users of metallic mercury in connection with industrial instrumentation. It is intended to give collectively the best available information concerning safe and efficient handling of mercury in the field. Since all possible applications cannot be listed, only the more common are covered.

Additional copies of ISA RP11.1 are available at 50 cents each and may be obtained from the Instrument Society of America, National Office, 1319 Allegheny Avenue, Pittsburgh 33, Pennsylvania.

National Committees and Chairmen

Society Structure and Planning
Nelson Gildersleeve

Nominating
G. F. Akins

Constitution, Rules & Procedures
R. L. Galley

Instrument Industry
Charles L. Saunders

Finance
J. T. Vollbrecht

Meetings and Exhibits
E. J. Grace, Jr.

Publications
C. W. Covey

Sections and Membership
M. D. Shriver

Employment
P. V. Jones

Intersociety Relations
Everett S. Lee

Public Relations
Douglas M. Considine

Government Relations
Ralph L. Goetzenberger

Educational Committee
Prof. Robert J. Jeffries

Historical
L. M. Susany

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Instrument Operation & Maintenance
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Testing Instrumentation
D. C. Little

Analysis Instrumentation
Axel H. Peterson

Instrumentation for Inspection & Gaging
W. A. MacCrehan

Instrumentation for Production Processes
W. H. Brand

Instrumentation for Transportation
F. H. Catlin

***Medical Instrumentation**

Meteorological Instrumentation
Christos Harmantas

Radiation Instrumentation
Richard W. Johnston

Geophysical Instrumentation
Dr. David S. Muzzey

***Physical Properties Measurement**

Aeronautic Instrumentation
Robert Tozier

Recommended Practices
A. V. Novak

**Chairman not assigned*

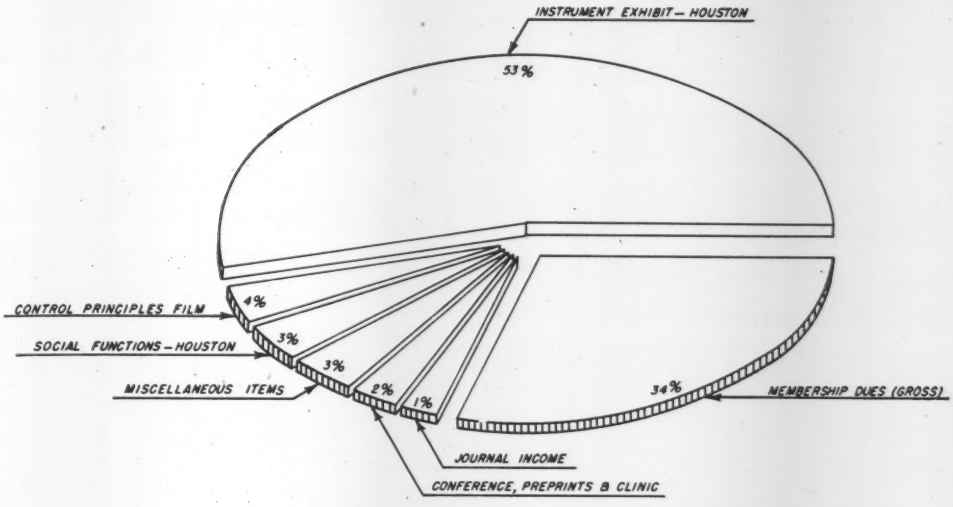
CIPP Announces Technical Program

W. H. Brand, Chairman of the Committee on Instrumentation for Production Processes, advises that a tentative program for the Cleveland Conference was formulated at a meeting of that Committee in Oak Ridge on February 16th. The sessions, chairmen, subjects, and speakers, where known are as follows:

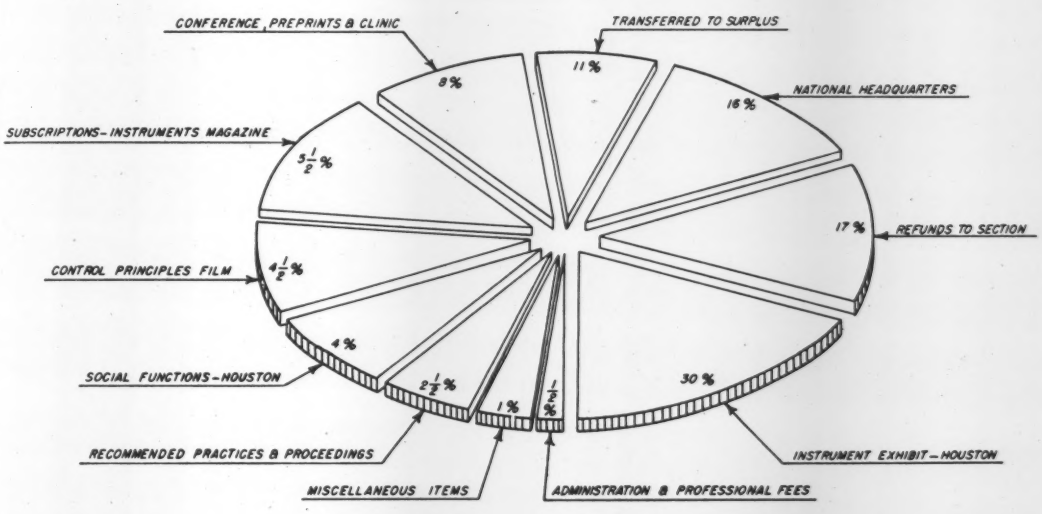
Monday, Sept. 8, 1952

Chairman—T. Pierson, Corn Products Ref. Co., Corpus Christi, Texas

YOUR I.S.A. DOLLAR —— WHERE IT COMES FROM



YOUR I.S.A. DOLLAR —— WHERE IT GOES



1. An Instrument for Sensing SO_2.
2. Quality Control for Alcoholic Beverage Production. Don Brandt, Schenley Distilleries.
3. Multipoint Monitoring System for Thermocouples.
4. The Mercury Jet Switch and its Application. R. G. Hoff, General Electric Company, Richland, Washington.

Tuesday, Sept. 9, 1952

Chairman—H. H. Johnson, Consolidated Edison of New York

1. Analysis of a Typical Cascade System Involving the Use of Pneumatic-set Ratio Relay.
2. Dynamic Behaviour of Pneumatic Devices. L. N. Gould and P. E. Smith, Jr., Mass. Institute of Tech., Dept. of Elec. Eng.
3. Comparison of Frequency Response Curves and Step Response Curves in the Field of Industrial Automatic Control. Dave St. Clair, Eastman Kodak Co., Rochester, New York.

Wednesday, Sept. 10, 1952

Chairman—Earl Seagrave, Celanese Corp. of America

1. Force Balance Pressure Transmitters Used to Detect Column Flooding. Gordon W. Swinney, Phillips Petroleum Company.
2. Plant Control by Gas Analysis. Bryon Dewey, Pure Carbonic Co.
3. Continuous Cellulose Cooker. Luke Paper Co.

Thursday, Sept. 11, 1952

Chairman—S. G. Eskin, Robertshaw-Fulton Co.

1. Controls as Applied to the Carrier Conduit System. L. Avery, Carrier Corp., Cleveland, Ohio.
2. Aircraft Cabin Temperature Control Systems. S. D. Browne, Clifford Mfg. Co., Waltham, Mass.
4. Automatic Control System for an All Year Air Conditioner. H. C. Shagaloff, Servel, Inc., Evansville, Indiana.
4. Controlling Domestic Oil Fired Heating Equipment. C. F. Suesserott, General Electric Company, Bloomfield, New Jersey.

Friday, Sept. 12, 1952

Chairman—R. N. Pond, Taylor Instrument Cos., Rochester, New York.

1. Instrumentation's Place in a Managerial Organization. Robert H. Berg, International Minerals & Chemical Corp. (Followed by contributed papers of approximately 15 minutes duration)

A. Interchangeable Panels—D. E. Haase
B. Open
C. Open
D. Open

Section Secretaries, Meeting Data and Programs

AKRON
Russell F. Marquardt, 1782 Tonawanda Ave., Akron 5, Ohio. Tel: ST-6865
Fourth Tuesday, Meeting 8:15 P.M., U. of Akron, Ayer Hall, Rm. 212-B.

ALBUQUERQUE
W. E. Bostwick, 304 So. Princeton, Albuquerque, N. Mex.
First Monday, Meeting at 8:00 P.M., Mitchell Hall, Univ. of N. M.

ARUBA
J. L. Lopez P. O. Box 203, c/o Lago Oil & Transport Co. Ltd., Aruba, N. W. I. Tel. 2087.
First Tuesday, 7:30 P. M., Engr's Club.

ATLANTA
M. Virgil Davis, 357 Sixth St., N.W. Atlanta, Ga. Tel. EM. 3042
Fourth Friday, Meeting 7:30 P.M., Electric Bldg., Georgia Power Co.

BALTIMORE
G. B. Greer, 631 East 36th St., Baltimore 18, Md. Tel: CHesapeake 6879
Second Friday, Meeting at 8:00 P.M., Engr's. Club of Baltimore.

BATON ROUGE
G. M. McCarroll, 1813 Edinburgh Ave., Baton Rouge 6, La.
Meeting monthly, L.S.U. Physics Bldg.

BOSTON
Stephen E. Lord, 60 Braintree Ave., Quincy 69, Mass. Tel: MA 9-1066
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 7:30 P. M., 99 Club, 99 State St.

CALIFORNIA
Gerald B. Miller, 4622 Halbrent Ave., Sherman Oaks, Calif.
Second Wednesday. Dinner at 6:30 P. M. Meeting at 8:00 P. M.
May 14, at the Elk's Club, 400 W. Colorado St., Pasadena. Subject: A Dual-purpose Mass Spectrometer. Speakers: C. E. Berry and P. S. Goodwin, Consolidated Engrg. Corp.

CAROLINA PIEDMONT
L. Frank Lawrence, Minneapolis-Honeywell Regulator Co., 2400 Wilkinson Blvd., Charlotte, N. C.
Second Friday, Cardinal Restaurant, Charlotte, N. C.

CENTRAL ILLINOIS
H. R. Getz, 723 Laura Ave., Peoria 5, Ill. Tel: 4-2800
First Wednesday. Dinner at 6:30 P.M., Meeting at 7:30 P.M.

CENTRAL INDIANA
Norman Krone, 123 N. Grant Ave., Indianapolis, Ind. Tel: IRvington 5337
First Tuesday, Meeting at 7:30 P. M.

CENTRAL NEW YORK
H. G. Murray, 169 Durston Ave., Syracuse 6, N. Y. Tel: 9-9259
Third Monday. Dinner at 6:00 P. M., Meeting at 8:00 P. M.
May 19, Meeting at General Electric Company, Subject: Instrumentation in Ceramics. Speaker: Dr. F. P. Hall, Pass & Seymour.

CHARLESTON
D. A. Cunningham, 5140 Washington Ave., S.E., Charleston, W. Va. Tel. 55403
First Monday, Dinner at 6:15 P.M., Meeting at 8:00 P.M., Kanawha Airport Terminal Bldg.

CHICAGO
Floyd E. Ertsman, Rm. 1420, Fisher Bldg., 343 S. Dearborn St., Chicago 4, Ill. Tel: WE 9-0686
First Monday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Hotel Shoreland.

CHINA LAKE
Beuhring W. Pike, 606-A Essex Circle, China Lake, Calif. Tel: 77782
Third Thursday, Meeting at 8:00 P.M., Michelson Lab, USNOTS, Conference Room.

CINCINNATI
R. J. Eichner, 1900 Courtland Ave., Norwood 12, Ohio. Tel: Jefferson 3130
Second Monday, Dinner at 6:30 P.M., Meeting 8:00 P.M., Engineering Soc. of Cinn.

CLEVELAND
G. D. Carnegie, 3436 Lorain Ave., Cleveland.
Second Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P.M., Cleveland Eng'r. Society, 2136 E. 19th St.

COLUMBUS
E. M. Chandler, 91 E. Como Ave., Columbus 2, Ohio. Tel: JE 9994.
Third Thursday, Meeting at 8:00 P.M., Battelle Auditorium

CUMBERLAND
Clyde Babst, 225 Cecelia St., Cumberland, Md. Tel: 583-W
Fourth Wednesday, Dinner at 6:30 P. M., Meeting at 8:00 P. M., Alighan Shrine Country Club, Baltimore Pike.

DENVER
G. M. Peters, 3191 W. Denver Place, Denver 11, Colo. Tel: GRand 9073

DETROIT
Frank R. Davis, Edison Institute, Dearborn, Mich. Tel: LO 1-1620 Ext. 5517
Third Tuesday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Rackham Bldg.

EASTERN NEW YORK
Robert W. Carter, Sterling-Winthrop Research Institute, Rensselaer, N. Y. Tel. Albany 5-6251 Ext. 262
First Tuesday, Meeting at 8:00 P.M., Siena College, Loudonville, N. Y. Optional Dinner at 6:00 P.M., Circle Inn, Lathams, N. Y.
June 3, Subject: Instrumentation of Airline Aircraft. Speaker: M. G. Beard, Chief Eng., American Airlines.

GULF COAST
Harold Placette, 2440 Neches Ave., Port Arthur, Texas
Last Tuesday, Meeting at 7:30 P. M., Orange County Courthouse, Orange, Texas.

HOUSTON
A. Costa, 714 East 17th St., Houston 8, Texas.
Last Monday, Meeting at 8:00 P.M., University of Houston Library Building.

KANSAS CITY
J. C. Brous, 8827 Maiden Lane, Kansas City 5, Mo. Tel: HI 8556
First Tuesday, Meeting at 7:30 P.M., U. of Kansas City, Science Bldg., Rm. 106.

LOUISVILLE
C. M. Bosworth, 5336 Westhall Ave., Louisville, Kentucky. Tel: FR 3494
First Monday, Meeting at 8:00 P.M., Seagram Auditorium.

MONTREAL
L. E. Henne, Bristol Co. of Canada Ltd., 712 Dominion Square Bldg., Montreal, Quebec, Canada Tel: UNiversity 6-4725.
Last Monday, 8:00 P.M., Mechanic's Institute.

NEW JERSEY
L. H. Ballinger, 2371 Channing Ave., Westfield, N. J. Tel: Westfield 2-0765M
First Tuesday. Meeting at 8:00 P.M., Essex House, Newark.

NEW ORLEANS
W. H. Haney, 2927 Music St., N. O. 22, La.
No Regular Date, Meeting at 8:00 P.M.

NEW YORK
F. B. Leslie, 520 South 14th St., New Hyde Park, N. Y. Tel: FI-7-0645.
Last Monday, Dinner at 6:00 P.M., Meeting at 7:45 P. M., Hob Nob Club, 108 E. 41st St.

NIAGARA FRONTIER
Mrs. James L. Martin, 34 Manning Rd., Eggertsville 21, N. Y. Tel: WIndsor 0087
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., N. Y. State Inst. of Arts and Sciences, Buffalo.

NORTH TEXAS
R. E. Byers, 6000 Lemmon Ave., Dallas 9.

NORTHERN CALIFORNIA
Bert L. Anderson, 1951 47th Ave., San Francisco 16, Calif. Tel: SEabright 1-5030
Third Monday, Dinner 6:30 P. M., Meeting 8:00 P.M., Spengers Grotto, 1919-4th St., Berkeley.

NORTHERN INDIANA
J. Baum Beckman, 7145 Wicker Ave., Hammond, Ind. Second Tuesday, Meeting at 7:30 P.M., Whiting Community Center, Whiting, Ind.
May 13, Subject: Selecting and Applying Butterfly Valves and Operators. Speaker: From R-S Products.

OAK RIDGE
George Ritscher, 113 Gorgas Lane, Oak Ridge, Tenn. Tel. 5-1084
First Wednesday, Meeting at 7:30 P.M., Ridge Recreation Hall
May 7, Subject: "Autronic," a complete Electronic Control System. Speaker: C. J. Swartwout, The Swartwout Company.
June 4, Demonstration and lecture on Use of Low Temperature Eutectic Welding Alloys for use in Instrument Design by the Eutectic Welding Alloys Corp.

ONTARIO
John W. Huether, 311 Southerland Dr., Leaside, Ontario, Canada. Tel: HU-7114
Third Thursday, Meeting at 8:00 P.M. Friendship Hall, College St. United Church, Toronto

PANHANDLE
Bruno F. Loewen, Philips Chem. Co., Box 1526, Borger, Texas.
Third Tuesday, Meeting at 8:00 P.M.

PERMIAN BASIN
J. B. Jenkins, 509 South Ave. "C," Kermit, Texas. Tel: 3220
Second Tuesday, Meeting at 7:30 P. M., Gulf Oil Corp. Auditorium or Odessa College.

PHILADELPHIA
R. A. Trenner, Energy Control Co. Rm. 304, 3147 N. Broad St., Philadelphia 32, Pa. Tel: SA 2-7900
Third Wednesday, Meeting at 8:00 P.M., Bellevue-Stratford Hotel.

PITTSBURGH
W. C. Langerman, Fisher Scientific Co., 711 Forbes St., Pittsburgh 19, Pa., Tel. Express 1-1330
Fourth Monday, Dinner at 6:30 P.M., Meeting at 8:00 P.M., Roosevelt Hotel.
April 28, Section Program, Subject: The Research Laboratory and Instrumentation. Speaker: Dr. Axel H. Peterson, Mellon Institute.
Program of the Technical Committee on Inspection and Gaging, Subject: Inspection of Industrial Furnaces. Speaker: Robert Buckholdt, Salem-Brosius Co.
Program of the Technical Committee on Industrial Instrument Maintenance, Subject: Demonstrations on the Repair, Set-up and Adjustment of Instruments made by the Foxboro Co., Speaker: A Foxboro service representative.
May 26, A visit to the Aluminum Company of America Research Laboratory, New Kensington, Pa.

PRESQUE ISLE
Edwin P. Schuwerk, 445½ Halley St., L. P. Erie, Pa. Tel: 2-3349
Fourth Tuesday, Meeting at 8:00 P.M., G. I. Community Center, East Lake Rd., Erie, Pa.
April 22, Election of Officers. Film—"Principles of Automatic Control."
May 27, Subject: Instrumentation of Rocket Flight Testing. Speaker from General Electric Company.

RICHLAND
T. H. Quinn, 1513 Goethals Dr., Richland, Wash. Tel: 7-8717
Second Wednesday, Meeting at 7:30 P.M. American Legion Hall.

ROCHESTER
R. C. Schwarz, Jr., Foxboro Co., 1201 Granite Bldg., Rochester 4, N. Y. Tel: Hamilton 1468.
Fourth Tuesday, Meeting at 8:00 P.M., Univ. of Rochester, Physics Lecture Hall.

SARNIA
L. J. Hall, 730 Talfourd St., Sarnia, Ont., Canada. Tel: EDgewater 2258.
Second Monday, 8:00 P. M., Y.M.—Y.W.C.A.

SOUTH TEXAS
H. C. Givens, La Gloria Corp., P.O. 637, Falfurrias, Texas. Tel: 122-W
First Wednesday. Meeting at 7:30 P.M.

SOUTHERN MICHIGAN
Lyle J. Draper, 2233 Oakland Dr., Kalamazoo, Mich.
Fourth Wednesday, 8:00 P. M., Dinner at 6:30 P. M., Chicken Charlie's, Kalamazoo.

ST. LOUIS
W. G. Lee, 4710 Delor St., St. Louis 16, Mo. Tel: FL 8516.
First Wednesday After First Monday, Meeting at 8:00 P.M., Engineer's Club of St. Louis.

TOLEDO
P. H. Girkins, 418 Waggoner Blvd., Toledo 12, Ohio. Tel: LA 6505
Third Tuesday, Meeting at 8:00 P. M., Service Bldg., Toledo Edison Co.

TENNESSEE
James L. Williams, 2237 Bruce St. Kingsport, Tenn. Tel: 2079-L
Fourth Thursday, Civic Auditorium.

TULSA
S. M. Bagwell, 1544 E. 35th Pl., Tulsa 5, Okla. Tel: 7-6822
First Monday, Meeting at 7:30 P.M., Engineering Bldg., Tulsa Univ.

TWIN CITIES
Jerome J. Schwab, Engineering Sales, 516 Guardian Bldg., St. Paul 1, Minn. Tel: GArfield 0601
Fourth Tuesday, Dinner at 6:30 P.M., Meeting 7:30 P.M., Rm. 353, Coffman Memorial Union, U. of Minn.

WASHINGTON
Edward C. Lloyd, 2105 Spencer Road, Silver Spring, Md. Tel: SH. 9340.
Third Monday, Meeting at 8:00 P.M., P. E. P. Co. Auditorium.

WAYNE COUNTY
J. R. McCauley, 18073 Archdale, Detroit 19, Mich. Tel: KE 1-5239.
Third Monday, Meeting at 8:00 P.M., Larson's Cafe, Lincoln Park, Mich.

WILMINGTON
E. Avery Taylor, Taylor Instrument Co., Industrial Trust Bldg., Rm. 510, Wilmington, Del. Tel: 9814.
Third Tuesday, Meeting at 8:00 P.M. Harlan Public School, Wilm.

ISA EMPLOYMENT SERVICE

Forward your letter to INSTRUMENT SOCIETY OF AMERICA
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Continued on page 478

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One hundred and thirty-five engineers turned out on a stormy night to see the Instrument Society film "Principles of Automatic Control" starring Messrs. Akins and Kowalski of Eastman Kodak and then listen to a talk on Automatic Control Analysis by N. B. Nichols, former Director of Research for Taylor Instrument Companies, and now Manager of Research for Raytheon Mfg. Co.

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Problems in Slurry Service Instrumentation

By P. D. SCHNELLE and R. K. SCHMOYER*

IN THE application of measuring and control instruments to chemical processes, one of the more difficult applications is with process fluids which tend to physically foul the instrument sensing elements. These process fluids range from miscellaneous "gunks," which may be removed from the bottom of a distillation column, to highly refined product materials in crystallizers. It is the purpose of this paper to discuss the general problem of instrument fouling due to the presence of various types of slurries and sludges. Particular emphasis is given to slurries and sludges which possess large positive temperature coefficients of solubility such as are encountered in many inorganic and organic phase separation operations.

Each slurry is unique, and indeed, unique even from day to day. Each slurry must be considered on its own merits. Certain principles of coupling instruments to process fluids, however, may be applied to slurries which conform to certain general characteristics. For the purposes of this paper slurries are divided into three classifications, namely:

(1) Slurries in which the suspended particles are not appreciably more soluble at high temperatures than at low temperatures and which have practically no colloidal or suspensoid properties. Settling of the slurry in the suspension medium is ordinarily of considerable importance. Examples of these slurries are encountered in the metallurgical and ceramic fields.

(2) Slurries in which the suspended particles are not appreciably more soluble at high temperature than at low temperatures and which exhibit colloidal or suspensoid properties, such as drilling muds and other thixotopic mediums.

(3) Slurries in which the suspended particles are appreciably more soluble at one temperature than at another temperature and which may or may not have a tendency to settle out because of the density solubility difference. This type of slurry is frequently made use of in the chemical industry for phase separation and will be referred to in this paper as "mother liquor" type.

Mother Liquor Type in Chemical Industry

The third classification of slurry is probably of the greatest importance in the chemical industry. Because control of crystallization is sometimes vital to quality of the product, this type of slurry requires and justifies more highly advanced instrumentation techniques. It is also somewhat more difficult instrumentwise. For this reason the discussion herein will be chiefly concerned with mother liquor type slurries. It is hoped that the principles to be brought out in the discussion of mother liquor type slurries will serve to demonstrate a rather wide range of techniques and will probably cover some of the problems encountered in the non-temperature sensitive slurries.

Temperature sensitive slurries may be further subdivided into positive and negative types. Positive temperature coefficient slurries are those in which the solubility increases with an increase in temperature. Negative temperature coefficient type slurries are those in which the solubility decreases with an increase in temperature. Various materials possess various values of temperature solubility coefficients; materials such as sodium chloride possess small positive coefficients; materials such as anhydrous sodium sulfate have negative coefficients; other substances such as Epsom salts, hypo and many organic materials possess large positive coefficients.

The so-called positive coefficient temperature sensitive slurry is probably the one most frequently encountered in phase separation operations in the chemical industry and poses a more severe problem to instrument utility than the other types. Therefore, in the following discussion it is assumed, unless specific notation is made otherwise, that the slurry under discussion possesses positive temperature solubility characteristics.

Problem of Crystal Formation

The handling and processing of mother liquor stock, whose dissolved solute possesses positive temperature solubility characteristics, is best done at temperatures as far above the crystal formation point as is practical. When the fluid is maintained at an elevated temperature, conventional instrumentation techniques are applicable in many cases. However, rich mother liquors must frequently be metered at temperatures near or below the crystal formation temperatures. These cases introduce a special problem—that of crystal formation due to what may be termed "local cooling"; i.e., cooling of certain portions below that of the main body of the stream.

This is particularly important when this local cooling is induced by or takes place on the sensing portions of instruments, thereby causing crystal formation which tends to foul the instrument. The severity of the induced crystallization problem depends on the physical characteristics of the crystals, their cohesive and adhesive properties. Some crystals possessing low adhesive forces do not seriously attach themselves to the sides of vessels or to instrument sensing equipment.

Some types of crystals, on the other hand, attach themselves to objects within their grasp with great tenaciousness and "set up" with considerable strength. If strongly adhesive and cohesive crystals are formed within the extension chamber of a transmitting rotameter, for example, or the external float chamber of a liquid level controller, satisfactory operation of the instruments is not possible. Weaker and less tenacious crystals cause less difficulty.

Location of Sensing Element Important

Crystal formation in rich mother liquors possessing positive temperature solubility coefficients is a matter of temperature. The instrument engineer must therefore choose his instrument applications in such a manner as to prevent the sensing portion of the instrument from causing serious local cooling of the rich mother liquor stream. The placement of instrument sensing elements within the process piping and equipment is of paramount importance.

Sensing elements must not be placed in stagnate flow areas, as for example, in the external float chamber of a liquid level controller. If other considerations dictate the use of an external liquid level chamber, it may be provided with steam jacketing or with steam tracing and insulation. This steam jacketing or tracing must include the connecting lines and the block valves to the liquid level chamber.

The sensing portion of an instrument which must be inserted within a rich mother liquor should have, if possible, a physical shape which is not conducive to local cooling action. Such a device would be long and narrow to minimize heat conduction by thermal conductivity longitudinally along its cross section. The instrument can contribute or remove little heat to the process liquor and, therefore, must assume the environmental temperature.

An example of such a choice would be the selection of a displacer actuated torque tube type liquid level controller having the float directly within the process vessel. The displacer would at all times be in intimate thermal contact with the process fluid; and the hanger, being a longitudinal member possessing a small cross sectional area, could contribute little heat to the system.

This device would represent a preferred choice to a side-mounted float type level instrument whose fulcrum mechanism would be located on the side of the tank (usually in a stagnate nozzle) and would be in contact with the process fluid on one side and ambient

* E. I. Du Pont Co., Orange, Texas.

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Statements and opinions expressed herein are those of the authors, and not necessarily those of the Society.

temperature on the other side. By this means a path for the heat transfer is introduced and local cooling is a certainty. Crystal formation could easily prevent a fulcrum mechanism from operating and the level instrument would be rendered useless.

High Velocity Desirable at Taps

The location of temperature, flow, and pressure sensing taps at a region of high velocity or agitation is highly desirable both from dynamic response and fouling standpoints. Serious local cooling of a high velocity stream is unlikely and the erosive effect of a high velocity stream has a marked tendency to sweep clean the sensing equipment of any fouling. Occasionally it is necessary to increase the flowing velocity of a stream by means of an agitator or circulating pump to take advantage of this effect.

In crystallizers, for instance, the circulating pump suction usually can be kept clean and provides an excellent spot for a thermowell, level dip tube nozzle, or pressure tap point. Slight transfer lags, while dynamically undesirable, are distinctly to be preferred to a mal-functioning installation which has its sensing location within the crystallizer.

A level dip tube located in juxtaposition with the agitator will probably give a very noisy signal, but it may have a good chance of staying unplugged. The use of instrument sensing equipment having a superfinish surface is frequently useful in helping to prevent, or at least to minimize, fouling.

In the metering of rich mother liquors containing crystals which are sufficiently non-adhesive and friable, some conventional instrumentation techniques can be employed. Liquid level frequently can be determined by well-engineered displacer type instrument installations. Pressure and flow will respond to conventional pneumatic and liquid flushback techniques to keep the impulse lines open.

With severely adhesive and cohesive slurries, however, conventional techniques fail; it is necessary to couple the sensing equipment to the slurry with a column of hot mother liquor or inert liquid flushback. This is most advantageously brought about by the application of heat directly to the sensing elements. This consists either of heating the entire measuring element and impulse lines or of heating only impulse lines and having a hydraulic or mechanical seal to protect the instruments from the entry of process fluids.

Pressure taps are a particularly difficult problem and must, in severe cases, be handled by specialized coupling techniques such as mechanical seals or hydraulic flushback. These techniques will be described in greater detail later.

Problem of Crystals in Slurry

Instrument application to equipment which contains crystals in a slurry or sludge presents somewhat different problems than the handling of rich mother liquors. As has been outlined previously, with rich mother liquors, an attempt is made to prevent the formation of crystals by maintaining temperature above the crystallization point. In crystallizer work, on the other hand, crystals are already present and have to be dealt with directly.

Here again much of the problem depends on the physical properties of the crystals and particularly on their adhesive or cohesive properties. Heat must be applied to keep the impulse lines open; very hot flushback and steam jacketing frequently is used. In severe cases it is almost necessary literally to "burn" or melt a fluid channel through the crystals into the process stream in order to establish a mobile hydraulic column capable of transmitting pressure to the sensing instrument.

Occasionally inferential schemes can be used to an advantage where it seems nothing else will work. A case in point is determination of the circulating rate of a large crystallizer in which the feed is known to a relatively high degree of accuracy. When the crystallizer and feed temperatures are known, and the feed is introduced in the circulating pump suction, a reasonable determination of the circulating rate can be obtained by measuring the temperature rise downstream from the point of feed introduction. A differential temperature measuring instrument can, therefore, be used in conjunction with the flow measuring instrument to infer the crystallizer circulating rate.

Slurries of Negative Type

The preceding material has dealt with the general principles to be followed in instrument applications to mother liquors possessing the so-called positive temperature-solubility relations. If, however, the slurry has a negative temperature-solubility relation, a different approach is necessary. The instrument coupling problems are the same, but the methods of circumventing them become different; for example, cooling must be employed instead of heating.

The phenomenon of local cooling becomes one of local heating. The effectiveness of cooling various sensing equipment to prevent fouling will depend, of course, upon the magnitudes of the coefficients which are, in general, smaller than those commonly encountered with materials possessing positive temperature-solubility coefficients.

The application of a cooling medium is more difficult and expensive than the application of heat because much lower temperature differences and heat transfer coefficients are usually realized. The use of a diluent type coupling in the form of various types of flushbacks would probably be indicated if the process can stand the diluent. In general it would appear that the same principles and techniques are applicable; cooling being substituted for heating, of course.

Temperature Measurements

Let us now examine in somewhat greater detail individual process variables, bearing in mind the principles which have been outlined. Probably the most frequently measured variable is temperature. The measurement of temperature usually presents very little of a problem unless the control loop is such as to require an extremely rapid response.

If a temperature sensing device is to be truly representative of the temperature of the stream, it is necessary that it be in reasonably good thermal equilibrium with its environment. This being the case, there must be no significant local cooling in the vicinity of the thermowell and a well-designed thermowell should not foul in rich mother liquor service.

Thermal elements should be physically small, have satisfactory length to the diameter ratio, and should be highly polished to minimize crystal pickup. In slurry service where significant bulb fouling does take place, the thermal lag depends on the adhesive and cohesive properties of the slurry and can only be mitigated by the location of a properly designed thermowell at a point of high fluid velocity or agitation.

Flow Measurements

The measurement of flows of mother liquors and crystalline slurries possessing severe plugging and fouling characteristics is extremely difficult. It has been found that by minute attention to detail in the design of flow meter installations it is possible to make flow measurements with reasonable instrument utility. Instrument utility considerations sometimes outweigh precision and accuracy considerations.

It has been the experience of the authors that properly engineered orifice and venturi installations hold the most promise for this service. The application problems of orifice type flow metering in rich mother liquor flow measurements are principally those of coupling. An attempt is made to couple mercuryless nondisplacement type transmitters to orifice and venturi flowmeters in such a manner as to obtain a maximum utility with a reasonable accuracy of measurement.

Vertical orifice runs are preferred in order to minimize the orifice fouling by the settling tendency of many slurries. The elevation of the transmitter with respect to the orifice should be determined by the method of coupling the transmitter to the process fluid. When a hydraulic coupling consisting of a liquid flushback is used, the transmitter elevation with respect to the sensing element will depend on the relative specific gravities of the process fluid and the flushing medium.

If the flushing fluid is lighter than the process fluid, the coupling must be made from above the orifice. If the specific gravity of the flushing medium is greater than that of the process fluid, the coupling should be made from below the orifice. Failure to observe this precaution will result in the "exchanging" of the two fluids in the impulse lines as may be seen from Fig. 1, and crystal

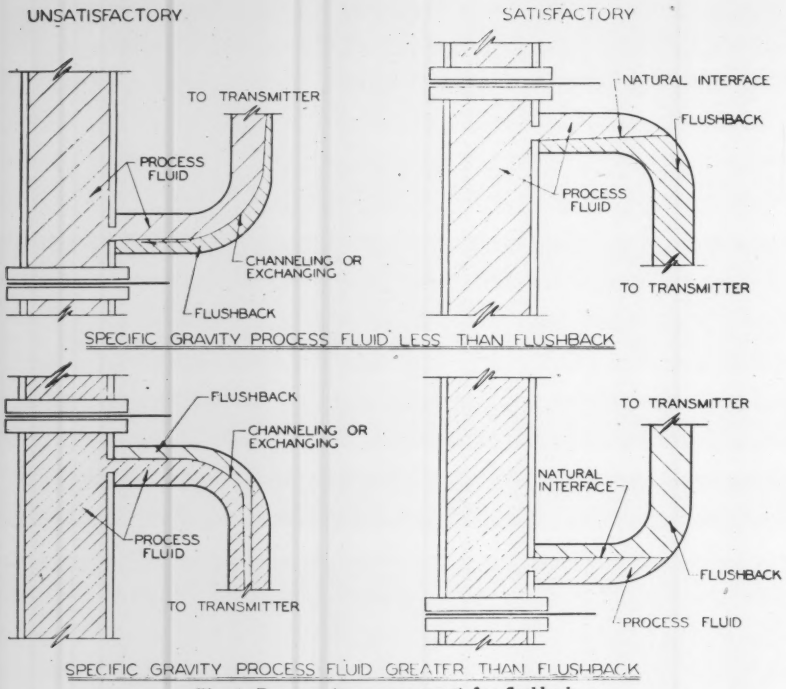


Fig. 1. Pressure tap arrangement for flushback.

formation due to local cooling will result in plugging. This fact is notwithstanding the complete miscibility or solubility of the flushback medium and the process fluid.

In short, the hydraulic coupling should be made in such a manner that a natural interface is established. The physical existence of the interface may be somewhat tenuous depending on the miscibility of the two fluids and the amount of flushback employed, but the necessity is very real. Impulse lines should be very short; the transmitter should be as close to the orifice as the necessary block and equalizing valves will permit. Examples of common mother liquor meters are shown in Figs. 2 and 3.

Use of Heated Lines and Seals

Another system of direct hydraulic coupling in which no flushback is used is a method which employs heated impulse lines which lead to a very close coupled, heated, mercuryless, non-displacement transmitter, or to an immiscible sealing fluid having a specific gravity greater than the specific gravity of the process fluid. These types, shown in Fig. 4 are most advantageously located below the orifice, since it is desirable to prevent the heated fluid in the impulse lines from exchanging with the process fluid, particularly if the process fluid happens to be a slurry. This location is also desirable to assist in filling and maintaining the seal.

Static meter seals are always undesirable, but in certain cases, such as for extremely corrosive materials and materials possessing a high crystallizing or solution point, they are justified. Frequently process materials are at a pressure higher than any medium available for flushback. Occasionally the process fluid cannot tolerate the diluent effect of the flushback. It should be pointed out also that flushbacks are really meter seals which are renewed continuously, as contrasted to the static or permanent type meter seals.

If a non-displacement, force balance, differential pressure transmitter is employed, conventional seal pots are not necessary as the seal levels never change appreciably. Non-displacement differential pressure transmitters are available with satisfactory over-range protection which reduces the possibility of losing the seal.

The choice between using a static or constantly renewable seal must be made on an individual basis, and depends on the availability of the satisfactory sealing medium. A static sealing medium must be inert chemically to the process fluids, and must be immiscible with and possess a higher specific gravity than the process fluid. It should also have a high boiling point since it will usually be contained in a steam jacketed or traced impulse line. It should have a relatively low viscosity at room temperature. An extensive search to find a satisfactory seal is justified if one is faced with a really difficult high temperature crystallization problem where the use of a flushback seal is not indicated.

Use of Mechanical Seals

In certain types of slurries and mother liquors where it is not desirable to seal hydraulically, it is possible to seal mechanically. An excellent example of this technique was recently described by Warren* and is shown in Fig. 5. In this scheme two mechanical, force balance, pressure transmitters are employed to seal and transmit the pressures on the upstream and downstream sides of an orifice.

These devices merely reproduce the process pressure upstream and downstream from the orifice to a high degree of accuracy within the limits of their ranges. The output from the transmitters is applied to a differential pressure transmitter which transmits a signal indicative of the flow. This is an example of the difficult problem nicely solved.

At higher pressures it is possible to use the previously mentioned static hydraulic coupling technique and also seal the instrument mechanically by using a conventional bellows or a limp diaphragm. This essentially gives a "filled system" differential pressure transmitter and is shown in Fig. 6. This system is considerably more elaborate to manufacture and to maintain. The tracing and jacketing of the seals sometimes become quite complicated.

This scheme is a makeshift. What is really needed is a commercial filled system differential pressure transmitter suitable for slurry usage. Filled system pressure transmitters are currently available for gage pressures, but to the authors' knowledge a filled system for differential pressure suitable for slurry-sludge service is not offered.

* *Taylor Technology*—Autumn 1950, Vol. 3-2, page 7.

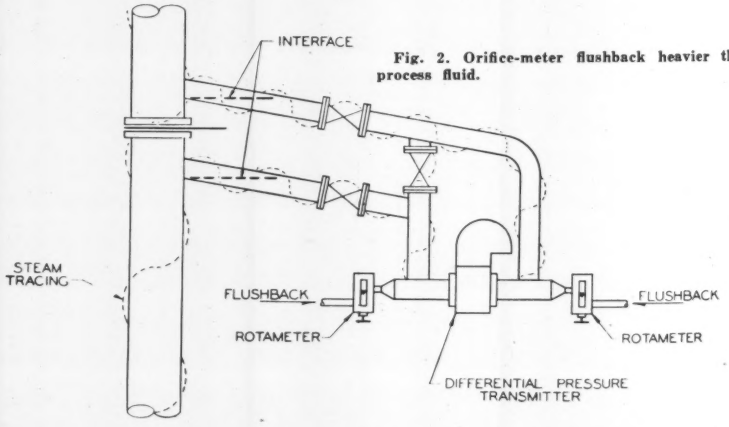


Fig. 2. Orifice-meter flushback heavier than process fluid.

Fig. 3. Orifice-meter flushback lighter than process fluid.

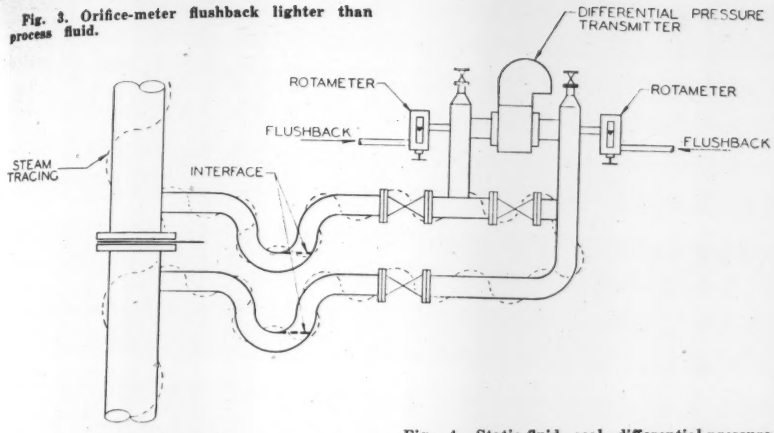
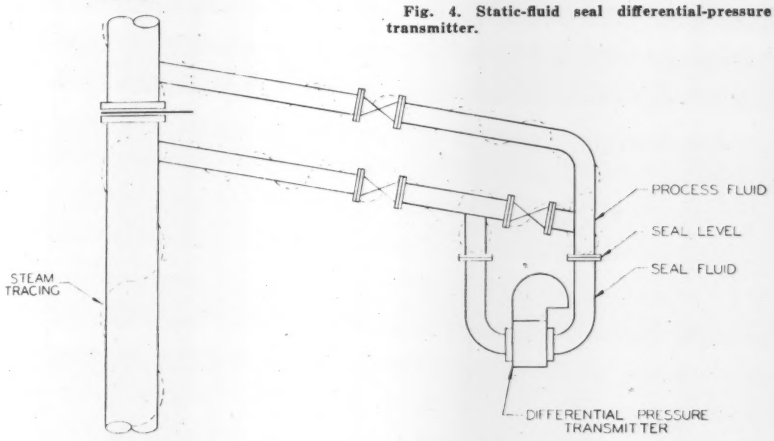


Fig. 4. Static-fluid seal differential-pressure transmitter.



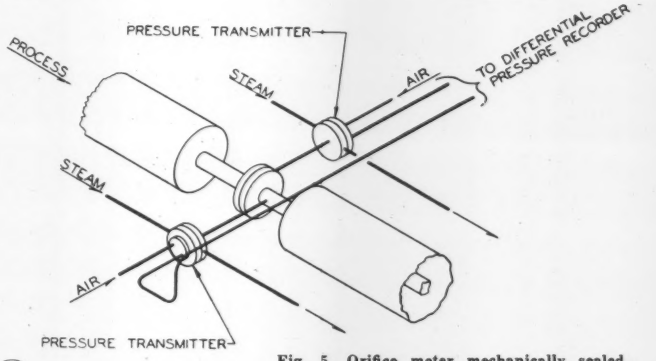


Fig. 5. Orifice meter mechanically sealed.

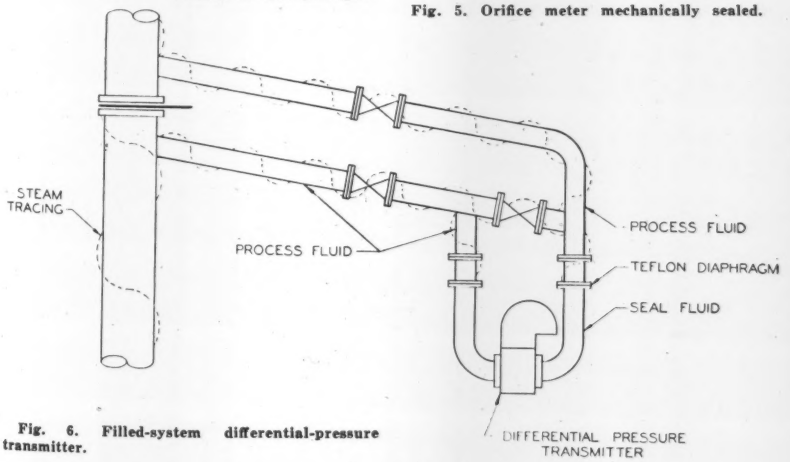


Fig. 6. Filled-system differential-pressure transmitter.

Factors in Precise Flow Measurement

The accuracy and precision of flow measurement of slurries and rich mother liquor depends on the degree of success enjoyed by the instrument engineer in coupling the transmitter to the orifice or venturi. The instrument must be coupled in such a manner to detect the pressure with a high degree of precision and accuracy and yet the disturbance to the normal stream flow pattern must be kept to a minimum.

In rich "mother liquor" stocks, when these techniques are applied and flushbacks are kept very small, the accuracies of the installations appear to approach those of more favorable installations. In slurry and sludge service the accuracy is an individual consideration. Frequently Reynolds numbers are low, physical properties of the fluid are more subject to change with particle size temperature, etc., local heating effects of heated impulse lines are more profound, and miscellaneous difficulties make it an achievement to obtain accuracies of ten to fifteen percent. For accurate work individual calibration is recommended.

Area type flow meters would appear to possess certain advantages in the measurement of the flow of rich mother liquors and slurries because of the absence of impulse lines. It has been found, however, that the extension arm of the transmitting type instruments presents a plugging problem at least equal to that of an orifice impulse line. It must be flushed back with a column of lean mother liquor, steam or some other suitable medium.

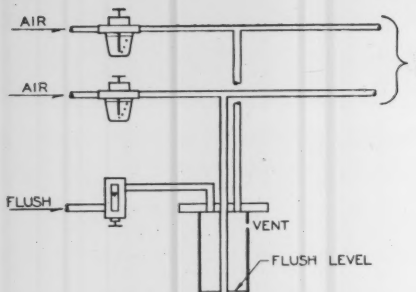
One real objection to the area type flow meter is, that when it does plug solid with a crystalline mass, it is much harder to clean or flush than an orifice or a venturi flow meter. Also it is much more difficult to maintain the entire assembly above the crystallizing point of the slurry if this is desirable. These features, in the opinion of the authors, even the score with orifice type meters and leave the decision to be made on the basis of the individual merit of the two flow measuring instruments.

Pressure and Liquid Level Measurements

Pressure measurements succumb to the same techniques applicable to flow measurements since measurements of flow entail measurement of pressure. The installation of a simple $25.00 pressure gage frequently calls for several hundred dollars worth of auxiliary flushback equipment to keep it in operation.

The measurement of liquid level in tanks of rich mother liquor and crystallizers is a difficult problem because mother liquors and slurries frequently foul the moving portions of sensing elements and prevent proper operation. Considerable success has been achieved even on exceedingly difficult problems employing level dip tubes of a special design.

The conventional dip tube, which em-



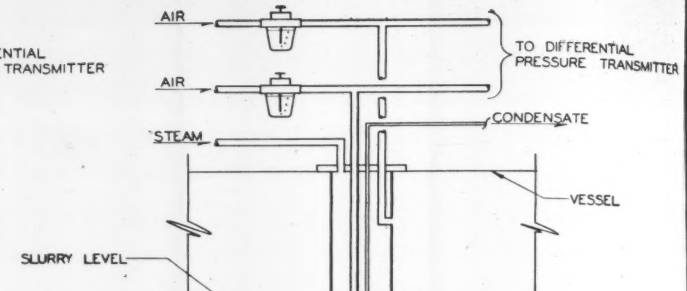


Fig. 7 (left). Concentric flush dip tube. Fig. 8 (right). Steam-jacketed dip tube.

ploys only a pneumatic blowback, has been found to become clogged very quickly. However, it was found that by employing a concentrate dip tube as shown in Fig. 7, a fluid column is continuously flushed and balanced against the process head. The outer dip tube is filled with water, lean mother liquor, or other flushing mediums and is vented at the top so that the flush column and the process column will be in balance.

A constant flush of lean material is added at all times to the outer dip tube to insure that the flow is out of the dip tube. This serves to keep the rich mother liquor or crystals washed out. The height of the lean column is determined by a conventional pneumatic blowback dip tube system, and the level of the process fluid can be inferred from the depth of the sealing fluid with consideration being given to the specific gravity relation between the two fluids.

This scheme has been found to work satisfactorily even in very heavy and adhesive slurries. It is frequently desirable to provide an internal heater within the flushing column to deliver the flushing medium to the process at a high temperature. Insulation of the outer dip tube in this case would be helpful.

Use of Heated Dip-Tube and Displacer Type

In cases where the fluid injection is undesirable or impractical—for reasons such as excessive dilution of the process, contamination, short operating ranges, or much pumping action—another type level dip tube has been developed. This is a steam-heated or jacketed dip tube such as shown in Fig. 8. The level dip tube is concentric within the jacket which is maintained at a high temperature either by steam heating or with a heating medium. This has proved to be successful on a difficult application. One of these devices is currently in operation sensing a liquid level over a total range of five inches of water using a simple pneumatic blowback.

Displacer type liquid level instruments have been found to be satisfactory in less severe services. The vertical displacer, torque tube type level controllers are preferred. The level chamber should be internally mounted through a nozzle in the top of the tank and not in a separate external float chamber unless it is elaborately steam-jacketed and traced and, perhaps, provided with a flushback.

The displacer chamber for the internally mounted liquid level displacer should be a vertical type with small pressure equalization holes in the top and with the bottom open. Thus it is possible to inject steam or hot lean mother liquor into the top of the level controller housing and to free the displacer when it occasionally hangs up due to crystal formation. This scheme has the further advantage of protecting the displacer from floating scum or froth which tends to deposit crystals on it.

If conventional loop type float guards are employed, it is impossible to free the displacer without opening the vessel when the displacer becomes attached to one of the loops or becomes fouled with a layer of crystals which has settled to the bottom of the tank. The effectiveness of this enclosed type float guard can be increased by the application of flushback techniques. The flushback should be applied directly into the displacer chamber.

Other Level Measuring Devices

Another type of level indicating device is the mechanically sealed force balance type of level indicator. These devices usually consist of a metallic diaphragm which is mounted on the end of a dip tube and is submerged within the tank. The diaphragm is forced inward by the hydraulic pressure of the fluid and operates to throttle the air bleeding from a nozzle. This movement is opposed by pneumatic feedback arrangement. The pressure feedback is a measure of the level in the tank. These devices should accommodate themselves to the environmental temperature, and with reasonable luck should perform satisfactorily.

Review of recent developments in the field of tank gaging disclose devices based on ultrasonic reflections and radioactive attenuation sensing systems. These devices, while more complex and expensive, will also enable the instrument engineer to look through a vessel wall into the tank with the complete absence of any coupling problem. They will enable the instrument engineer to differentiate between levels and phases in the tank. Levels in a field of tanks can be conveniently registered in one central location with one instrument.

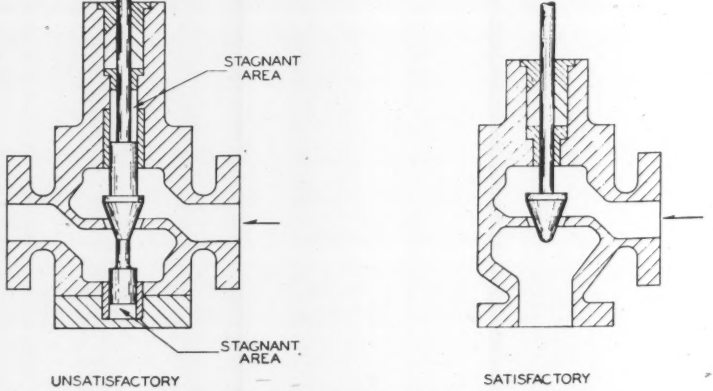


Fig. 9. Control valve for slurry service.

Control Valve for Slurries

The selection and specification of control valves for rich mother liquor and slurry service is vital from both a control and a process standpoint. Frequently a chemical process can be operated with inadequate or mal-functioning instrumentation, but it cannot be operated with control valves that will not open or close. In many cases vital safety considerations add emphasis to these selections.

Control valves for slurry and mother liquor service should resemble the piping itself as closely as is physically possible. Control valves should be selected to hold a minimum of stagnate fluid in the valve bodies. They should be selected with consideration being given to the design of valve guide bushings which must necessarily contain stagnate fluid at certain lift conditions, and which, upon cooling, may crystallize and prevent the valve plug from moving. An example of this type valve is shown in Fig. 9.

These considerations dictate the selection of the single seat and single top guided valve. This type valve is currently available either as a straight-through globe valve or as an angle valve. Proper choice should be based on careful selection of the valve interior with consideration being given to crystal interference with the valve plug motion and any other plugging possibilities. When the service is extremely severe, it is necessary to provide the valve with steaming or flushing connections both above and below the seat.

The instrument application methods and principles enunciated in this paper represent the thinking and experience of the authors. They are not represented as a panacea for all problems of instrument fouling due to the presence of slurries, sludges, and gunks. It is hoped, however, that some of the principles mentioned may promote and stimulate useful thinking on the part of the reader and will perhaps assist in the solution of other problems.

An A-c Induction Flow Meter

By W. G. JAMES*

RECENTLY when a critical flow metering application arose at Oak Ridge National Laboratory, a review of various flow meters disclosed that the induction flow meter had so many promising characteristics that it warranted a thorough investigation. The results of such an investigation as they apply to low flow rates are presented herein.

Most of the commonly used types of liquid flow meters[1] are based upon mechanical principles — such as the measurement of a pressure drop across an orifice or the displacement of a vane, float, or propellor inserted into the flow channel. The application of these principles to the precise measurement of flow rates below 50 milliliters per minute, for extended periods, becomes difficult. The constrictions of, or protrusions into, the flow channel usually create plugging difficulties, and considerable pressure drop is required if the primary signal is to be sufficiently large for simple and accurate measurement. The caloric flow meter[2] overcomes some of these difficulties but its operation is sluggish and its calibration is dependent upon several liquid constants such as specific heat, thermal conductivity, and viscosity.

The induction flow meter does not suffer from any of these difficulties; it's many advantages are enumerated below:

(1) Response linear with flow rate.
(2) Calibration independent of type of flow (laminar or turbulent).
(3) Calibration independent of density, viscosity, specific heat, thermal conductivity, temperature, and, theoretically, conductivity of the liquid.
(4) Absence of lag.
(5) Absence of constrictions of, or protrusions into, the flow channel.
(6) Absence of pressure drop.
(7) Production of an electrical signal by the primary detector.

The disadvantages are that the liquid must be at least slightly conducting in practice, and the signal for a flow rate of 50 milliliters per minute requires electronic amplification for good detection. When compared with the many advantages, these two disadvantages lose much of their significance.

Theory of New Meter

The induction flow meter is based on the "generated emf" interpretation of Faraday's law of induction: a conductor moving relative to a magnetic field will have induced in it a voltage proportional to its velocity in accordance with the relationship:

$$e = B.l.v \times 10^{-8} \qquad (1)$$

where e is the induced voltage in volts, B is the flux density in gauss, l is the length of the conductor in centimeters, and v is the velocity of the conductor in centimeters per second and the directions of B, l, and v are mutually perpendicular. [3]

The physical arrangement by which this principle might be employed to measure a liquid flow rate is shown in Fig. 1. The liquid whose flow rate is to be measured is channeled between the poles of a magnet. The motion of the liquid relative to the magnetic field will cause a voltage to be induced in the liquid proportional to its velocity.

This emf is transferred to the electrodes which are imbedded in the walls of the conduit, flush with its inner diameter and in contact with the liquid. The emf is then amplified sufficiently to actuate an indicator or recorder. Since the emf is proportional to the velocity, which in turn is linearly proportional to the flow rate, the amplifier output will also be linearly proportional to the flow rate.

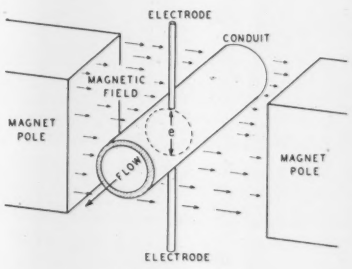


Fig. 1. Basic flow detector.

The magnetc field may be either alternating or direct; for a direct field a d-c signal is obtained, and for an alternating field an a-c signal is obtained. For either arrangement, the induced emf is given by

$$e = 1.06 \times 10^{-10}\ (BF/R) \qquad (2)$$

where e is the d-c or the peak a-c signal in volts, B is the magnetic field strength in gauss, F is the average flow rate in milliliters per minute, and R is the inner radius of the conduit in centimeters. The derivation of this equation[4] is based on assumptions that the flow is axially symmetric, the velocity vanishes at the walls, and the conductivity of the conduit is much less than that of the liquid. These conditions are fulfilled to a sufficient extent in most practical setups.

History

Faraday himself seems to have been the first to consider using this principle to measure a flow rate. It is reported[5] that he unsuccessfully attempted to detect an emf induced in the River Thames as a result of the tidal motion of this body of water across the earth's magnetic field.

Williamson[5] reported a successful application of the principle in 1930, and since then Kolin and others[7-22] have reported several applications of the principle. Kolin apparently was the first to use an alternating magnetic flux with an induction flow meter and, since his introduction of this method in 1937, it has been used almost to the complete exclusion of the direct field method.

A Specific Design

The induction flow meter described herein was designed to meet the following requirements:

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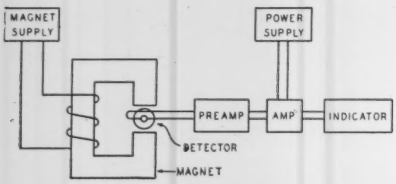

Fig. 2. Component arrangement—A-c induction flow meter.

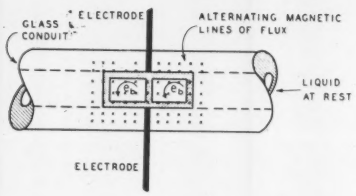

Fig. 3. Enlarged detector tube.

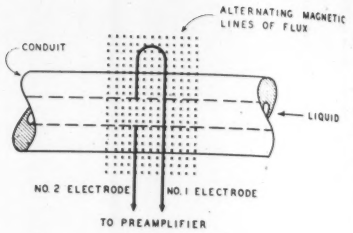

Fig. 4. Detector electrode arrangement.

(1) Withstand the corrosive action of nitric acid.

(2) Withstand 10^7 roentgens of gamma radiation.

(3) Measure a flow of 40 milliliters per minute with an accuracy of $\pm$ 5 per cent over a period of four hours.

(4) Operate from a power line having $\pm$ 15 per cent changes in line voltage.

(5) Have a minimum flow channel restriction of 1/8 inch.

(6) Have two detectors, only one of which would be operated at any given time.

A block diagram of the instrument is presented in Fig. 2.

An a-c magnet is used because the signal obtained from a flow of 40 milliliters per minute is so small that it cannot be measured readily with standard d-c techniques. Operation on a-c also eliminates troublesome polarization of the electrodes which occurs when a d-c current flows through the liquid from one electrode to the other.

Unforutnately, the use of an alternating magnetic flux produces sources of voltage that are not related to the flow rate. The two such "background" voltages that are most troublesome are:

(1) Capacitively coupled voltages from the magnet coil to the electrodes.

(2) Induced loop voltages in the liquid and electrodes.

Voltages from the first source are minimized by operating the magnet with its outer winding at the lowest possible a-c potential, by electrostatically shielding the electrodes, by grounding the maget core, and by using a low frequency of magnet excitation so that the impedance of the coupling capacity will be large. Background voltages from the second source are of a larger order of magnitude in most cases and are not so easily minimized.

Nature of Background Voltages

How these background voltages, having no relationship to the flow rate, are induced in the liquid is shown in Fig. 3 which is an enlarged view of the detector. If the incremental cross-hatched section of the liquid is considered as a conductor, effectively it is two secondary turns of a transformer. The voltages e_b induced in these turns will be proportional to the rate of change of flux by which the turns are coupled.

If conditions were such that the voltages induced in the two turns produced exactly equal and opposite currents in their common leg, there would be no resultant voltage between the electrodes for the condition of zero flow. Unfortunately, because of inhomogeneties in the flux and the liquid, such conditions do not usually exist. As a result, there is a voltage present between the electrodes and this voltage varies as do the impedances of the liquid on opposite sides of the electrodes.

The average value of this voltage can be "bucked out," but the variations cannot be; therefore, they will appear as random variations in the output whether there is a flow or not. Fortunately, these variations are small compared with the signal from a flow of 50 milliliters per minute.

To buck out this average background voltage the electrodes can be so located that the voltage induced in them will be equal in magnitude and phase to the background voltage but opposite in polarity. Fig 4 shows that the electrodes themselves form a secondary transformer turn when the plane in which they lie is not exactly parallel to the lines of flux.

The polarity of the induced voltage will be determined by the location of the No. 1 electrode with respect to the No. 2 electrode. When the No. 1 electrode is to the left of the No. 2 electrode, the polarity of the induced voltage will be the opposite of that induced when No. 1 is to the right of No. 2. By trial, the location required to buck out the background voltage can be determined.

Benefit of Low Frequency of Magnet Excitation

Induced background voltage can be decreased in magnitude by employing a low frequency of magnet excitation, since the voltage will be proportional to the time rate of change of the flux. If the flux is a sine wave of amplitude B and frequency f, the voltage will be given by:

$$e_b = k\ (d/dt)\ (B \sin 2\pi f t) = 2\ k\ B\ f \cos 2\ \pi\ f\ t \qquad (3)$$

where k is a proportionality constant. Under the same conditions, a signal resulting from a constant flow would be directly proportional to the instantaneous magnitude of the flux and therefore, would be given by

$$e_s = k'B \sin 2\ \pi\ f\ t \qquad (4)$$

where k' is another proportionality constant. Comparison of the two equations reveals that as the frequency is lowered, the background voltage decreases, while the signal voltage remains constant.

Another advantage of using a low frequency of magnet excitation is that by so doing, the power line frequency noise voltage can be more effectively rejected. From these considerations, it would seem desirable to go to very low frequencies, but doing so brings up other difficulties.

First, the response time of the instrument may be determined in part by the frequency of the signal. For instance, it is obvious that faithful response to a 0.1 second flow transient can not be obtained if the magnet excitation frequency is one cycle per second since, during the transient, only a small fraction of one cycle would have elapsed. Second, polarization effects may become significant within one cycle if the frequency is sufficiently small. Third, the amplifier and magnet supply design become increasingly more difficult as the frequency is decreased below a few tens of cycles per second. With these considerations in mind, a magnet excitation frequency of 11.7 cycles per second was chosen.

Design of Magnet and Detector Tube

The magnet core is formed of laminations from a 60 cycle-per-second filament transformer. The coil consists of 5500 turns of AWG No. 26 magnet wire which gives an inductance of 11 henrys with a Q of 6.5. With 100 volts rms across the coil a flux density of approximately 1500 gauss is obtained.

The magnet supply is a conventional Wein bridge oscillator[23] and power amplifier. Its output is series-resonated with the magnet coil by an 18 microfarad oil-filled condenser. Since the coil has a Q of 6.5, this arrangement appreciably decreases the driving requirements. The supply can deliver up to 130 volts rms across the coil but is normally operated at 100 volts. Fig. 5 is a schematic diagram of the supply.

The detector tube designed to fulfill the first two requirements of an induction Flow Meter (as listed earlier) is shown in Fig. 6. The tube itself is pyrex glass and the electrodes are platinum. The ¼-inch loop in the longer electrode is for the purpose of introducing the voltage required for

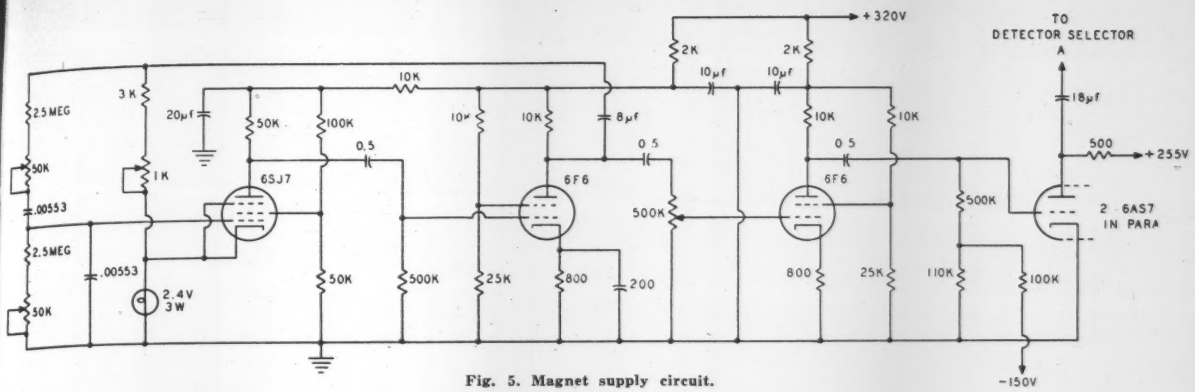

Fig. 5. Magnet supply circuit.

bucking the background voltage previously discussed. The loop can be twisted in either direction to pick up a voltage of the proper polarity and the amount of twisting can determine the magnitude of the bucking voltage. The connector to which the electrodes are secured can also be twisted to locate the long sections of the electrodes in such a position that they will pick up a bucking voltage, also. This makes a convenient "fine" adjustment.

The detector tube is gasketed to the stainless steel tubes of the system by means of spring-loaded glands and teflon gaskets. Teflon was selected because of its high resistance to the corrosive actions of acids. To cause the teflon to flow sufficiently to insure a good seal, 2000 psi pressure are required. This necessitates the thick walls of the tube. The glands and their tie-bolts serve to short any ground currents in the liquid around the detector tube and thus help to reduce noise voltages in the system. Fig. 7 shows the arrangement of the magnet and detector assembly.

Detector Selector Switch

The output from the detector goes by way of a shielded two-conductor cable to a "detector selector" switch as shown in Fig. 8. This switch permits the operator to select either of two detector-magnet assemblies (not shown on diagram) and to test the instrument with either of the assemblies. When, by means of the switch, a particular assembly is selected for operation, its magnet is connected to the magnet supply and its detector is connected to the preamplifier input; the other unit is disconnected.

The over-all operation of the instrument can be checked, with either assembly, by putting the switch in the appropriate "test" position (see Fig. 8). In the "test" position, the detector output is disconnected from the preamplifier input and a signal obtained from a wire-wound resistor in series with the magnet coil is applied in its stead to the preamplifier. In this manner a signal is obtained which is proportional to magnet excitation.

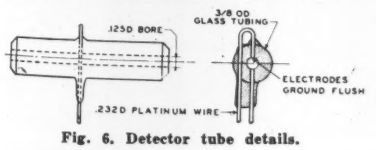

Fig. 6. Detector tube details.

Since, in order that the instrument stay calibrated, the product of magnet field strength and amplifier gain must be constant, this signal, which is proportional to magnet current and thereby field strength, should give a specific output. This output is determined at the time the instrument is initially calibrated. At any later time this check can be performed and the gain of the amplifier can be adjusted to give the specified output.

This check is seldom required, however, since, as will be shown subsequently, the calibration is automatically corrected for changes in magnet excitation. Also, with the amount of regulation used in the amplifier, its gain should vary only as aging causes the gain of the tubes to vary.

Preamplifier Circuit

The preamplifier is shown schematically in Fig. 8. Long-life tubes are used because the elimination of shut-downs is of prime importance. Fortunately, these tubes also have higher input impedances at low frequencies than do conventional tubes. This makes it practical to have a preamplifier with an input impedance of 44 megohms, which is desirable since it makes the instrument more independent of the conductivity of the liquid.

In order to increase rejection of both external and internal noise voltages, a push-pull circuit is employed in the preamplifier. External noise voltages due to ground and induced currents flowing axially in the detector tube are reduced in the preamplifier because these voltages are in phase, and the push-pull feature of the preamplifier permits its in-phase gain to be only about 1/400 of its push-pull gain. Internal noise voltages are more easily reduced in a push-pull amplifier because non-inherent noises such as hum and ripple will occur in phase on the

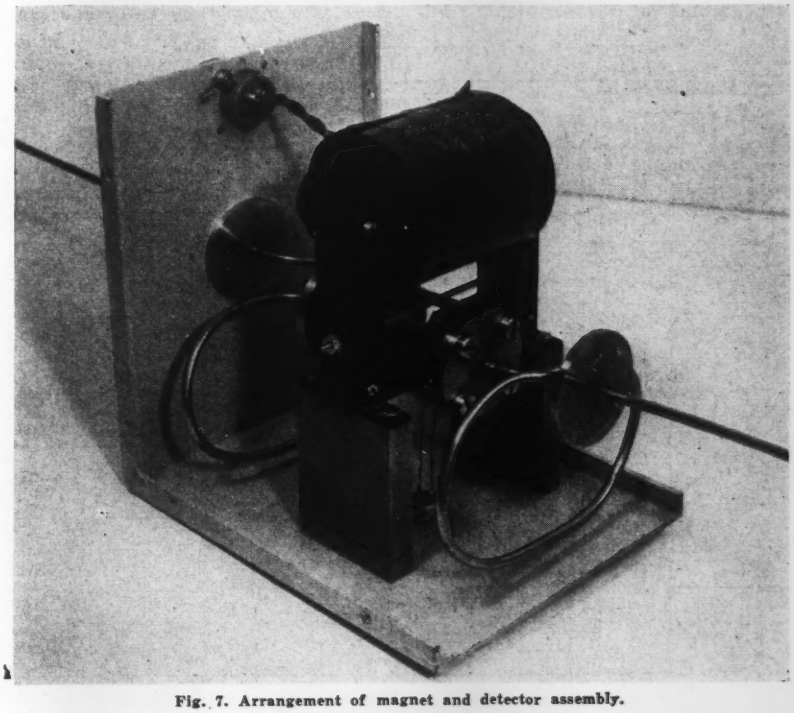

Fig. 7. Arrangement of magnet and detector assembly.

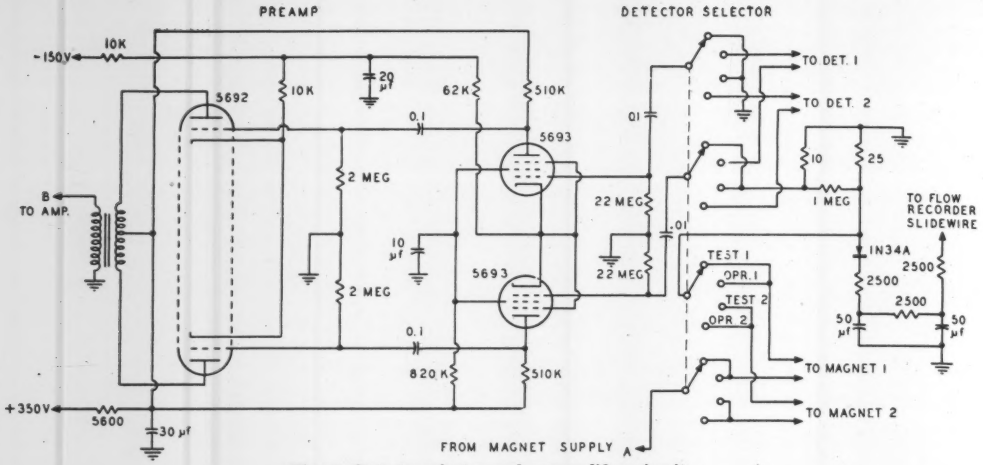

Fig. 8. Detector-selector and preamplifier circuit.

two sides and will therefore be amplified by the relatively small in-phase gain of the unit. Only two stages of push-pull amplification are used because the signal is then large compared to internal noise.

Despite the fact that the innerstage transformer used to convert to a single-ended signal is very inefficient at 11.7 cycles per second, it was used because it was readily available. A condenser was placed across its output to give some rejection to high frequencies. The over-all gain of the preamplifier is approximately 110.

Amplifier Circuit

The output from the preamplifier passes through a 60 cycle-per-second parallel-T rejection filter[24] which makes it practical to operate the preamplifier filaments directly from a-c. A bandpass network of the parallel-T feedback type[25-28] follows the rejection filter as shown in Fig. 9. Such a network has the characteristic that at one particular frequency, f_o, its voltage transmission from one side to the other is zero. This center frequency f_o is given by the expression:

$$f_o = \frac{1}{2\pi RC}$$

where R and C are as shown in Fig. 9. The transmission at other frequencies varies as their separation from the center frequency varies. Table 1 and Fig. 10 give the results obtained by the use of such a network in this instrument. The 6db bandwidth of the network is approximately one cycle-per-second centered about 11.7 cycles per second.

The output from the bandpass network is amplified by two additional stages of voltage gain and then rectified by a dual thermionic diode. The diode filament voltage is reduced so that the diode contact potential is less effective in upsetting the zero of the output. The use of a thermionic diode and large filter resistors eliminates the need for bulky filter condensers.

The rectifier output is fed to a balanced vacuum tube voltmeter driving a panel meter and to an external electronic null-type recorder. No zero adjustment is provided for the panel meter since with no input it reads zero. This is attributed to the fact that the diode contact potentials have been reduced and the two halves of 5692 dual triodes are exceptionally well matched.

The purpose of the panel meter is to aid in ascertaining whether or not the instrument is functioning properly and not to indicate the flow rate; flow rate is indicated by the external recorder.

The signal voltage for the external recorder is a small fraction (about ten millivolts) of one half of the rectifier output. Since a complete bucking of the background voltage cannot be ob-

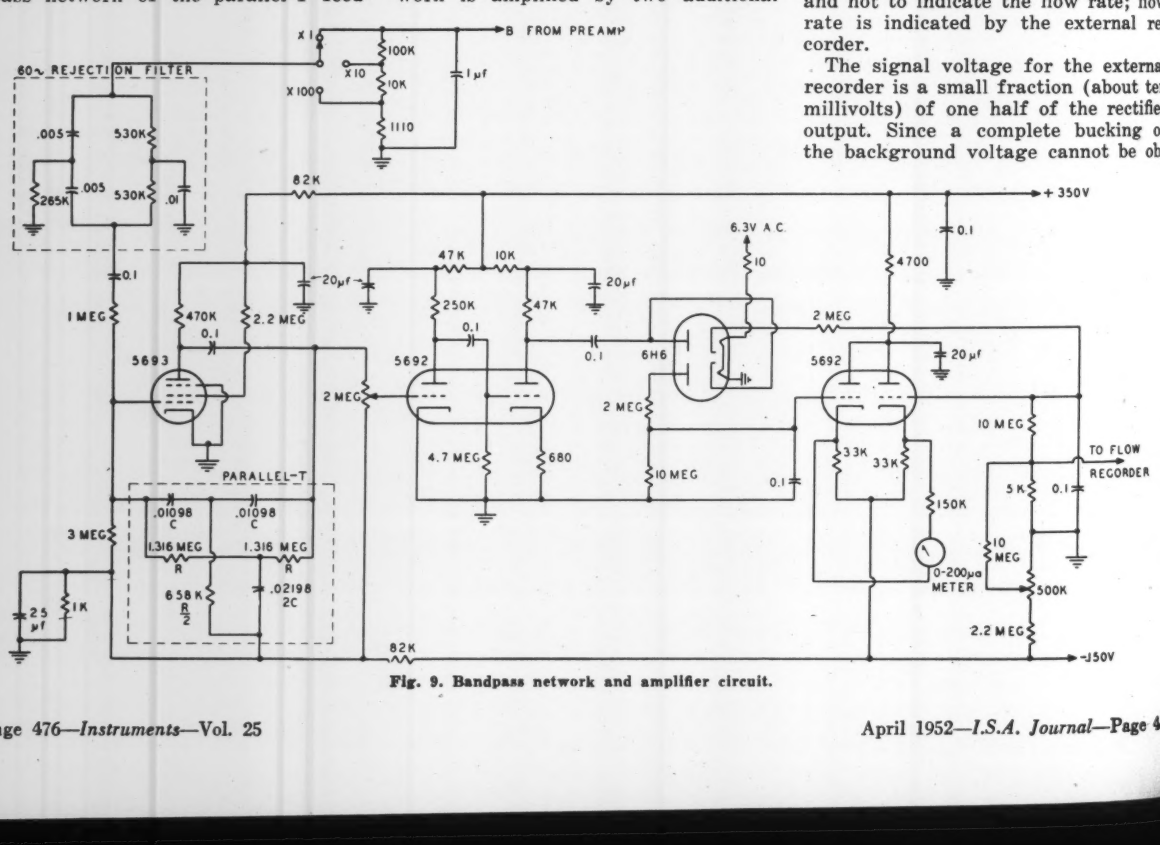

Fig. 9. Bandpass network and amplifier circuit.

TABLE 1—A-C INDUCTION FLOW METER AMPLIFIER FREQUENCY RESPONSE

Frequency	Relative Output
1.0	2.0
5.0	2.0
10.0	15.0
11.3	100.0
11.7	200.0
12.1	100.0
13.0	32.0
15.0	15.0
20.0	8.0
30.0	2.0
45.0	2.0
100.0	2.0

tained in this instrument, a zeroing adjustment is provided for the recorder so that it can be made to read zero when the flow is zero.

The recorder slidewire potential is obtained by rectifying the a-c voltage across a resistor in series with the magnet coil. By this arrangement, any change in the amplitude of the magnetizing current causes a percentage change in the slidewire voltage that is just equal to the percentage change caused in the output voltage. The result is that the recorder reading is unaffected by changes in magnet supply output. The preamplifier, bandpass network, amplifier, and rectifier are located on a 17 by 13-inch chassis on whose panel is located a gain control, detector selector switch, zero adjustment, and panel meter.

The $B+$ power supply for the amplifier is a conventional series-regulated type, and the $B-$ supply is regulated by VR tubes. The filaments are regulated to within $\pm$ 1 per cent by a constant voltage transformer because they were found to be the principal cause of changes in gain when the line voltage changed. The power supply is mounted on a standard 17 by 13-inch chassis and has an "ON-OFF" switch as its only control.

The performance of the preamplifier and amplifier have proved quite satisfactory. The output noise voltage corresponds to a preamplifier input voltage of approximately 0.25 microvolts rms, which will be shown to be equivalent to a flow of one-half milliliter per minute. The over-all gain is approximately 950,000 which permits an input voltage of 25 microvolts to drive the panel meter full scale.

The excellent linearity between input and output of $\pm$ ½ per cent of full scale is attributed to the fact that the output voltage of about 25 volts at full scale is much greater than the contact potential of the diode rectifiers, and also to the fact that all the vacuum tubes are operated within their linear range. The gain stability of $\pm$ 5 per cent for a $\pm$ 15 per cent change in line voltage is adequate; a more stringent requirement would have necessitated a feed-back amplifier.

When the components described in the preceeding paragraphs were assembled, the resultant instrument fulfilled all requirements with the possible exception of resistance to radiation. The latter feature is being checked by using the instrument in a location in which it will ultimately receive the prescribed radiation.

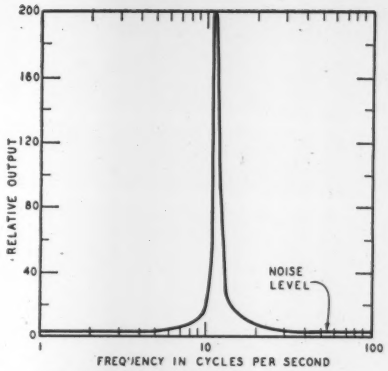

Fig. 10. Amplifier frequency response.

The electrode and magnet assembly gives a signal of 0.5 microvolt per milliliter per minute for liquids having conductivities at least as great as that of isopropyl alcohol. By optimum location of the electrodes, the background voltage in the assembly can be reduced to approximately 0.7 microvolt with tap water in the tube. With a 0.1 normal solution of NaCl in the tube, the minimum obtainable background voltage is about 0.4 microvolts; with singly distilled water, about 7 microvolts.

The variations are attributed to the variation of the impedance between the electrodes for the different liquids. Because of the impedance variations, the effectiveness of capacative and inductive coupling to the electrodes varies with liquid conductivity. This would not be of particular importance if it were not for the fact that within the amplifier chassis, there is background pickup by the preamplifier input leads, from the magnet supply lines. These lines are located in the chassis adjacent to the input leads to permit selection of the desired magnet and detector assembly.

The effective magnitude of this background voltage is determined in part by the impedance between the electrodes. When the impedance is high, sufficient bucking voltage cannot be obtained by twisting the electrodes to eliminate the background voltage. No provisions were made for obtaining more bucking voltage because the use of the flow meter for liquids less conducting than tap water was not anticipated.

In a unit having only one detector, the difficulty could be avoided by keeping the magnet supply leads well removed and shielded from the input leads. It should be noted that the variation in background from the NaCl solution to tap water was only 0.3 microvolt which is equivalent to a flow of less than one milliliter per minute.

CALIBRATION OF MEASURING SYSTEM

The linearity of the system was checked for tap water by using a constant-head tank, a pinch valve, a calibrated 50-milliliter flask, and a stop watch. Fig. 11 is a section of the recorder chart used on the output during the calibration run. After each change in flow rate, sufficient time was permitted for the flow rate to stabilize before a reading was taken. Each flow rate was then maintained for a time sufficient to fill the flask and the time required was measured with the stop watch.

The average recorder reading during this time was determined and plotted against measured flow rate in Fig. 12; the data is given in Table 2. Gain of the amplifier was maximum, and no zeroing current was used so that a more complete picture of the operation might be presented. The electrodes had previously been adjusted for minimum background voltage and for this test the instrument was operated from a regulated line.

Fig 12 shows that the sensitivity at maximum gain is 2.59 chart divisions per milliliter per minute flow; the maximum deviation from linearity is approximately one-fourth milliliter per

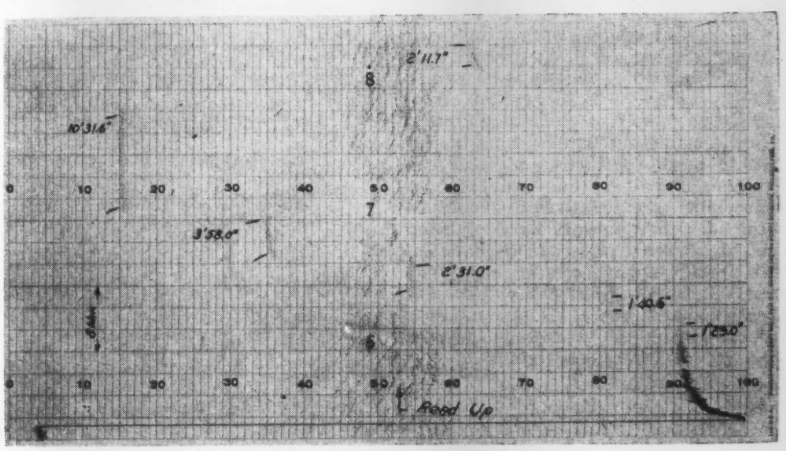

Fig. 11. Calibration recording.

Table 2—A-C Induction Flow Meter Calibration Data

Average Recorder Reading	Time for 50 CC, Seconds	Average Flow (Milliliters/Min)
4.3	———	0.00
15.3	631.6	4.75
35.3	238.0	12.60
54.6	151.0	19.86
63.0	131.7	22.78
81.0	100.6	29.81
91.0	89.0	33.72

minute. The chart in Fig. 11 shows that the uncertainty in a particular reading as about ± 0.5 division or ± 0.2 milliliter per minute. The zero flow output corresponds to 1.5 milliliters per minute. This, of course, could have been made to correspond to zero on the recorder merely by adjusting the "zero" control.

To check the stability of the instrument over a period of several hours, a constant displacement pump was used. An eight-hour run was made at a flow rate of 26 milliliters per minute with the instrument operating from a regulated line. During this interval the output varied a maximum of ± 1%. To these variations one must add those which would be caused by changes in line voltage if an unregulated line were used. The additional variations percentage-wise would be about one third the percentage variation in the line voltage.

Spot checks from day to day indicate that the stability for such periods is approximately the same as obtained in the eight-hour run. Of interest, also, is the fact that the calibration for tap water was unaffected by a change in water temperature of 50° C.

Conclusions

The theory of the induction flow meter has been presented and its application to low flow rates has been discussed. The results obtained with a particular design have been presented and from these one might conclude that, for the range of 0 to 50 milliliters per minute, the a-c induction flow meter is quite practical, providing the liquid conductivity is at least as great as that of tap water. For such liquids, one can expect a linearity of ± 0.25 milliliters per minute and a stability of ± 0.5 milliliters per minute if the supply is well regulated.

Less conducting liquids could be designing more specifically for this application, but it is questionable that appreciably greater stability could be obtained. Other authors have reported that higher flow rates can be handled, and probably with greater ease. The upper limit of practicality has not been reported but it is undoubtedly several orders of magnitude greater than 50 milliliters per minute.

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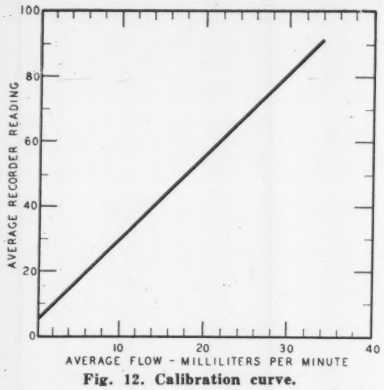

Fig. 12. Calibration curve.

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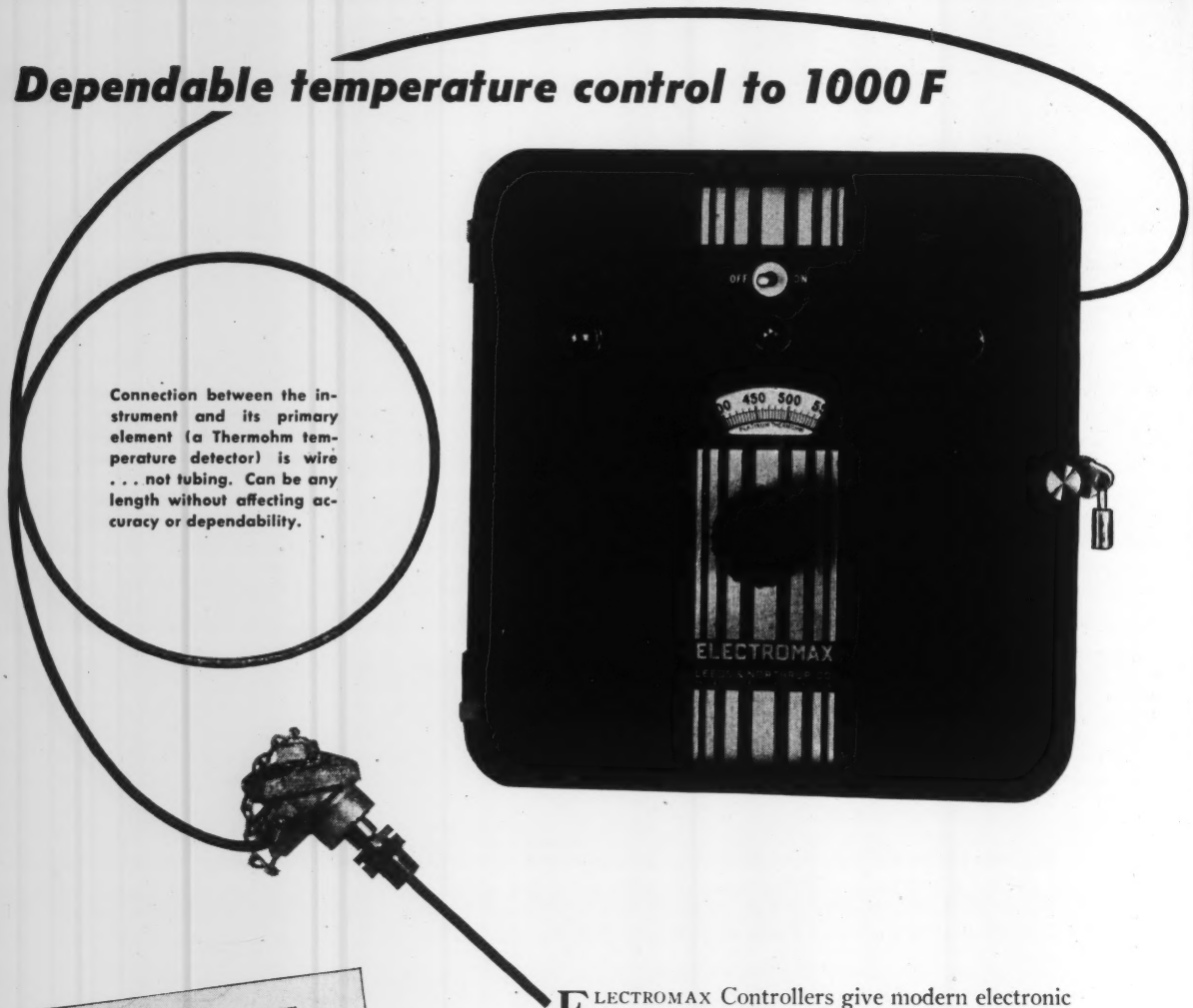

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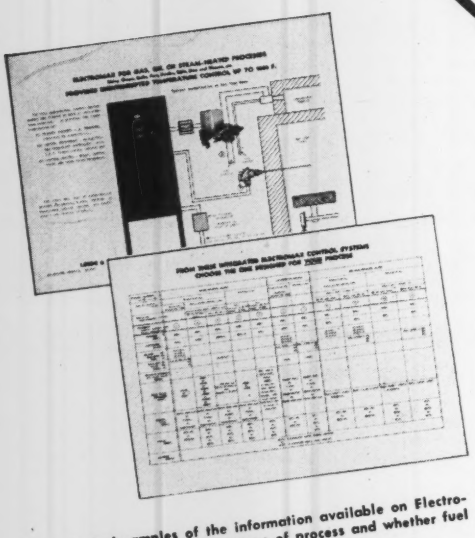

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Dynamics of Pulsative Flow through Orifices

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Principal Research Engineer

and IRA C. BECHTOLD
Manager, Research & Development

The Fluor Corp., Ltd.
Los Angeles, Calif.

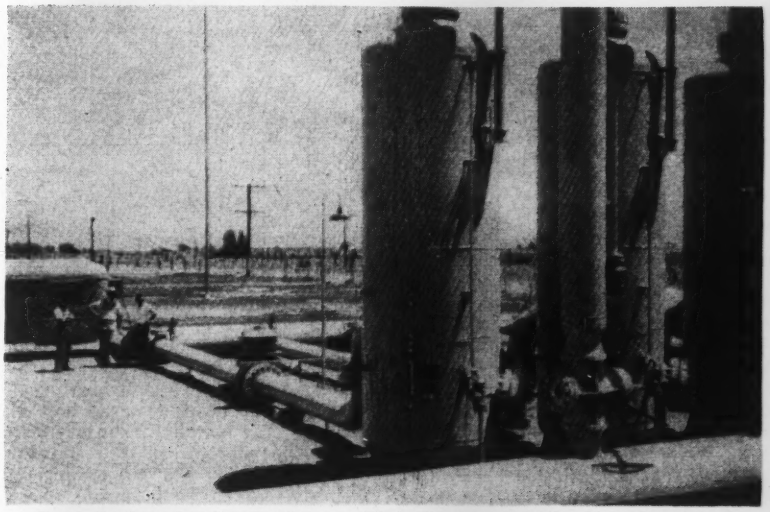

Fig. 1. Southern Counties Gas Company Blythe Compressor Station Meter from gas-cleaner side. A portion of Fluor Mobile Research Laboratory is in background.

The Bernoulli Equation

THE Bernoulli equation, formulated during the nineteenth century, related the static pressure with the dynamic pressure of a flowing fluid as follows:

Static pressure + Dynamic pressure = A constant.

As, for a given pipe size, the mass flow rate is proportional to the velocity of the fluid, the Bernoulli relation offered a practical means whereby the rate of flow of any fluid could be measured readily. By virtue of the mechanical simplicity of the metering equipment, the flow-metering requirements of services having large-volume gas flow are met to a large extent at present by orifice metering.

Several assumptions are implied in the use of the Bernoulli relation for metering flow. One assumption is that the instantaneous pressure distribution throughout the meter run is uniform. If this were not so, a correction term would be needed to account for the dynamic inertia of the fluid. One objective of this article is to show how rapidly-changing pressure conditions require drastic modification of the equations usually employed to compute the relations between pressure drop and flow in orifice systems.

The higher-order modifications which must be applied to the orifice equation to account for vena-contracta effect, Reynolds-number effect, etc., for steady flow conditions through the meter run, have been described by others.[1] However, comparatively little has been said concerning additional modification made necessary by high-frequency, unsteady flow conditions—particularly the effect of pressure pulses propagating with the velocity of sound through the meter run.

Because of practical considerations, both mechanical and economic, fluid usually is made to flow from one point to another by reciprocal-type compressors and pumps. A reciprocating compressor or pump produces discharge flow by ramming discrete quantities of gas into a pipe (vice versa for suction flow). As the action requires a sudden acceleration and deceleration of portions of the fluid, pumping is inevitably accompanied by pressure waves which propagate at acoustic velocity through the fluid in a pipe line.[8, 10, 11] The laws of propagation of sound waves apply to these pressure pulses. Experimental evidence reveals that the propagation of such pulsative energy is accompanied by a change in wave-shape, conditioned by a number of physical variables in the piping system through which the pulse travels.[8] Under conditions of pulsative flow, therefore, we endeavor to meter the mass flow rate of a fluid by means of an orifice restriction, even though one of the basic implied requirements of Bernoulli's theorem is ignored completely.

Fundamentals of Dynamic Systems

All dynamic systems—electrical, mechanical, and acoustic—can be described in terms of three elements. The first of these, the *kinetic element*, represents kinetic energy (or energy of motion); the second, the *capacitive*

Presented at the annual meeting of the ASME, Nov. 26, 1951, Atlantic City, N. J.

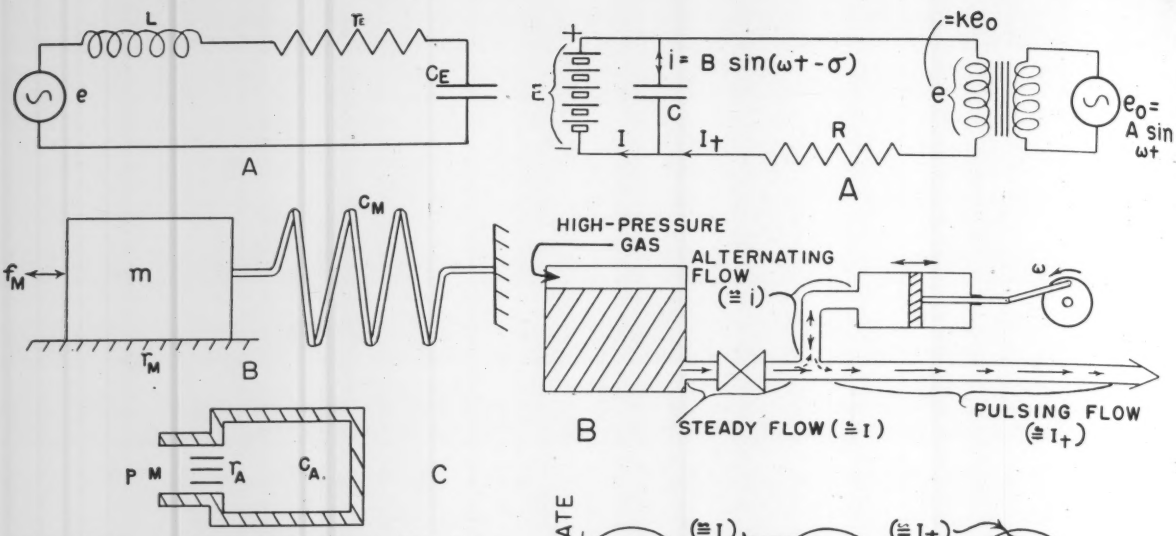

Fig. 2 (above). Analogous systems: A, electrical; B, mechanical (rectilinear); C, acoustical.

Fig. 3 (right). Addition of direct and alternating components for electrical current and hydraulic flow. A, electrical; B, hydraulic; C, d.c. plus a.c.

element, represents stored potential energy (or energy of position); the third, the *dissipative element*, dissipates kinetic energy by conversion to heat, thus producing a loss in the total energy in the system. An example of each of the three systems is given in Fig. 2.

The dynamic equations of each system in Fig. 2 are mathematically identical, the constants of the equations corresponding to the three basic elements. The systems each possess one degree of freedom. The reader is referred to the bibliography for additional material concerning dynamic analogies[6]; for the purposes of this article, it is enough to know that a great similarity exists from system to system. The usefulness of dynamic similarities in analyzing the orifice-metering problem lies in the fact that a mechanical or acoustical problem can be set up by using a simple electric analogy.

Two items should be reviewed before discussing the effect of pulsative flow on orifice metering—(1) the breakdown of pulsative flow into steady and alternating components, and (2) the concept of impedance. Fig. 3A shows a resistive load, R, connected through a transformer winding to a battery source of direct current. Coupled through the transformer is a source of alternating current which produces an alternating voltage, e, in series with the d-c. voltage, E. Thus R "sees" a total voltage $(E + e)$ at its terminals. If e is sinoidal, the total current flowing through R is:

$$I_t = (I + i) = I + B \sin(\omega t - \sigma) \qquad (1)$$

The capacitor C provides a battery-shunting flow path for i, the alternating current. Thus the current flowing through the load resistance consists of a d-c. component plus an a-c. component. Similarly, in the pipe line shown in Fig. 3B, the flow consists of two parts—one being the "d-c." flow in the absence of pressure pulsations, the other an "a-c." component caused by the reciprocating action of compressors (or pumps). Fig. 3C illustrates the addition of the alternating and direct currents to produce the resultant current or flow rate.

The Impedance Concept

Impedance is that part of an electrical circuit which impedes the flow of current. Impedance can be of two types—resistive or reactive. A resistive impedance resists the flow of both direct and alternating currents, whereas reactive impedance resists only the flow of alternating current.

The resistive component of impedance is the element which dissipates electrical energy in the form of heat. The reactive element, which does not dissipate energy per se, changes the phase and amplitude of the a-c. component. The total impedance of an electrical circuit can be written as follows:

$$Z = [R^2 + (\omega L - 1/\omega C)^2]^{1/2}, \qquad (2)$$

where R is the resistance, L is the inductance, C is the capacity, ω equals $2\pi f$, and f is the frequency of the a-c. component.

The foregoing implies that R, L, and C are discrete portions of an electrical circuit. That is to say, in electrical parlance, these elements are usually considered to be "lumped." However, such an assumption often cannot be made, especially when working at higher frequencies. A straight wire, for example, because of *distributed* L and C elements, does not behave as a pure resistance to the flow of current containing a high-frequency a-c. component. Owing to distributed L and C, the wire has an impedance referred to as *characteristic impedance*. Similarly there is a characteristic *acoustical impedance* of a pipe or conduit.

Reflection

If a-c. energy flows through a long line which has a characteristic impedance, Z_1, no reflection of the energy occurs so long as Z_1 remains constant along the line. However, if the size or shape of the line changes at any point, the characteristic impedance of the line changes at that point. Stewart[7] has shown that portion of the propagating a-c. acoustic energy is reflected at the discontinuity.

As the output of a pump or reciprocating gas compressor is analogous to the flow of a direct electrical current with a superimposed alternating current, reflection of the pulsation energy takes place at sudden changes in the pipe diameter, such as at take-off lines or at restrictions such as orifice plates.

The presence of an orifice plate in a meter run produces an abrupt change in the run's characteristic impedance, thereby reflecting a fraction of the incident pulsative energy.

This article assumes that the fundamental error in measurement of pressure drop across an orifice during pulsative flow occurs in the differential and not in the inferential measurement. This assumption has been substantiated by experimental research. Al-

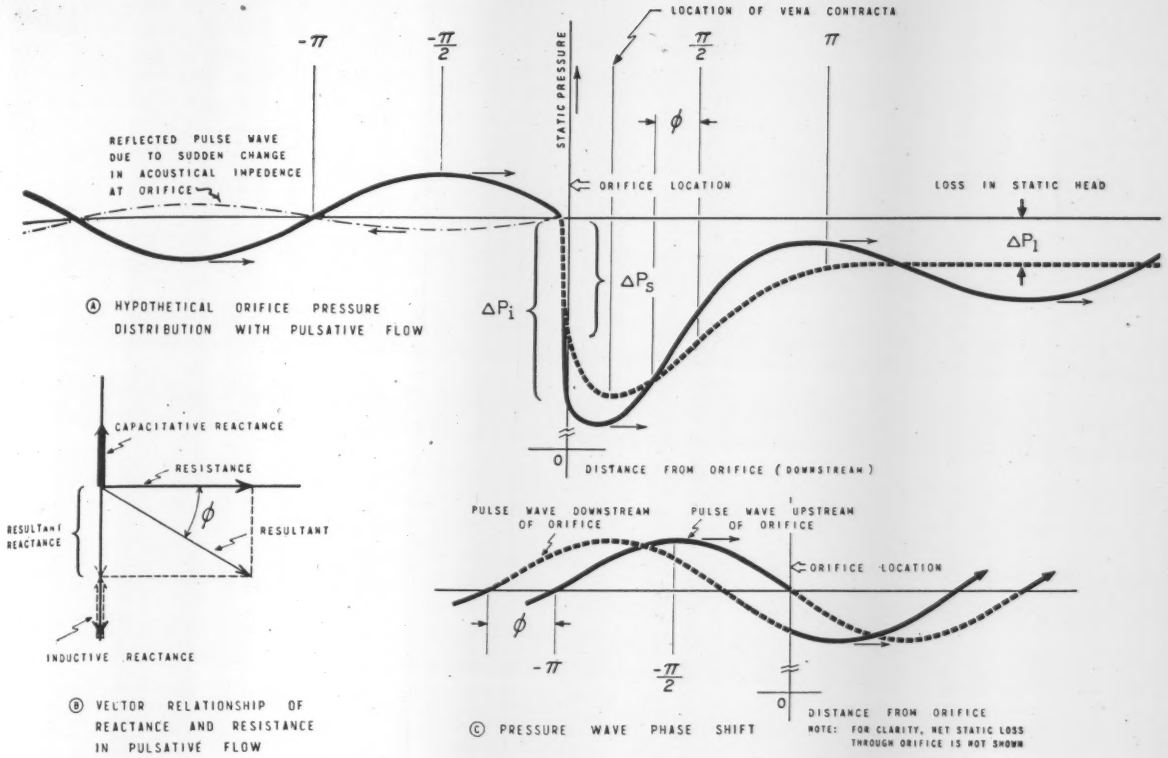

Fig. 4. Pulsative flow through an orifice.

though much difficulty may be experienced in the inferential accuracy because of acoustical resonance effects in meter leads and chambers, such effects may be minimized or eliminated easily.

The authors present two basic ideas which are believed to be pertinent to the solution of the metering problem. One of these at the present time does not appear to offer any simple approach towards reducing differential error, but has considerable basic significance in the consideration of this problem in a dynamic sense. This idea is referred to hereafter as *pulse phase-shift*—that is, phase shift of the a-c. pulsation component across the orifice plate together with a change of pulse wave shape. The other idea, which might offer a fertile approach to the solution of the fundamental problem, is based on dynamic measurements of the effect of reflection on static pressure. The latter is referred to hereafter as the *reflection theory.*

Pulse Phase-shift

From the acoustical standpoint, an orifice plate inserted in the pipe line has, in a more-or-less lumped condition, the three basic acoustical elements previously described. The reactive components, referred to as *inertance* and *capacitance*, operate with the *resistance* element to change the phase of the pulsation wave across the orifice. This is illustrated in Fig. 4. Fig. 4B shows the relation between the real pressure drop caused by orifice friction (resistance) and the reactive pressure drops caused by the inertance and capacitance. The addition of the three vectors shows the phase shift Φ. This phase shift is illustrated in Fig. 4C, where the dashed pressure waves represent the continuations of sinoidal pressure pulse waves upstream and downstream of the orifice.

Fig. 4A illustrates in a qualitative way the net effect of this phase shift, Φ, when superimposed on the pressure drop, $\triangle P_s$, produced by the d-c. component of the pulsation wave in giving the instantaneous drop $\triangle P_i$. The net static loss of the orifice is shown as $\triangle P_l$. A mathematical analysis of the effect of this phase shift (for a sinoidal pressure pulse) shows that the shift has an effect on the differential reading when the latter is averaged in time. Further, different frequency components of a complex wave usually undergo different degrees of both phase shift and attenuation. Therefore, the total energy content of the downstream wave may differ considerably from that of the incident wave. It appears from this that any flow-metering system based on time integration of the square root of the instantaneous differential pressure is in error by an amount depending on the totality of the phase-shift functions for each component of a complex pulse wave. On the contrary, except for certain other factors, greater accuracy would be achieved with a system based on time integration of the square root of the average differential pressure.

Reflection Theory

The reflection theory is based on the fact that the propagation of pulsation waves is a form of energy propagation which is directed vectorially. If some of the energy of this incident pulsation wave is reflected at an orifice plate, there should be an increase in static pressure on the reflection side of the orifice plate, analogous to electromagnetic radiation pressure. This should produce an average differential reading on the high side. If, on the other hand, the pulse energy which passes through the orifice produces a standing wave on the downstream side of the orifice because of acoustical resonance in the meter-run piping, such a standing wave may affect the pressure immediately downstream of the orifice plate to decrease the differential pressure. Thus, the reflection theory provides an explanation for anomalies which are observed to occur frequently in practice wherein one orifice meter may read high, another low, and still another may read either high or low, depending on beta ratio and d-c. throughput conditions.

Experimental Data

Experimental evidence which substantiates the reflection theory was obtained recently at the metering installation of the Southern California Gas Company—Southern Counties Gas Company, Blythe Compressor Station. The data obtained were of two general types—(1) electronic measurements of the a-c. component of static pressure

(pulse pressure), and (2) electronic measurements of the instantaneous differential pressure across orifice plates.

The installation is illustrated in Fig. 1. Five meter runs similar to the one shown in Fig. 1 are located immediately upstream of the compressor-station suction gas cleaners. Orifice meters are located in individual meter houses near the runs. Fig. 5 shows the method of installation of the electrical transducers for measuring instantaneous pulsation pressures and/or differential pressure. Oscillographic recorders were located in a mobile laboratory[12] from which shielded cables lead to the pressure pickups.

Similar data were obtained at considerable distance upstream from the Blythe Compressor Station; specifically, at the Ehrenberg Metering Station of the El Paso Natural Gas Company, and at a 24-in. check orifice-metering installation approximately 24 miles upstream from the Ehrenberg Station, also in the El Paso Natural Gas Company California line. Particularly at Blythe, a close correspondence was observed between differential pen swings and amplitude of the beat-frequency envelope of the pulsation wave generated by the non-synchronous reciprocating compressors immediately downstream from the meters on the other side of the gas chambers. The width of the beat-frequency envelope

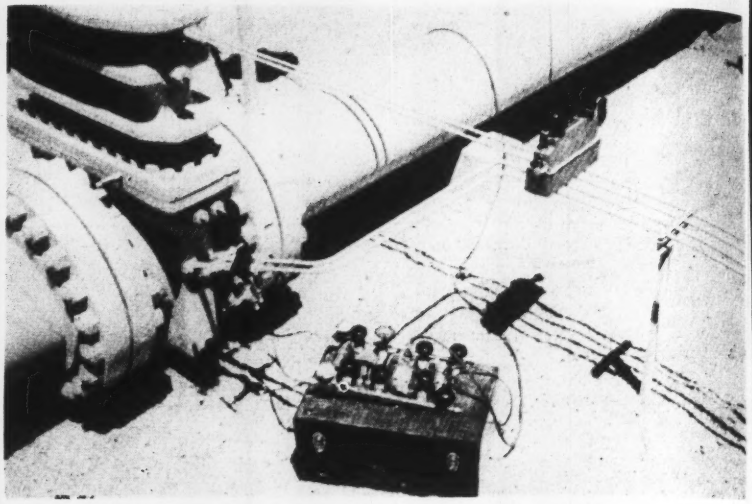

Fig. 5. Installation of transducers at orifice through tees, valves, and manifolding for obtaining instantaneous-pressure and/or differential-pressure recordings.

of the pulsation wave represents a variation in intensity of the pulsation wave. The one-to-one correspondence of peaks of such envelopes with maximum differential pen swings in the flow meters supports the reflection theory. The same phenomenon was observed approximately 6 miles upstream at the Ehrenberg Metering Station, and also at the check meter.

Frequency and Phase-Shift Analyses

Table I contains the results of frequency analyses of the upstream and downstream pulse waves for one of the orifices (flange taps). Although the upstream and downstream components are not directly comparable in intensity, inspection of relative intensities of the components for each indicates

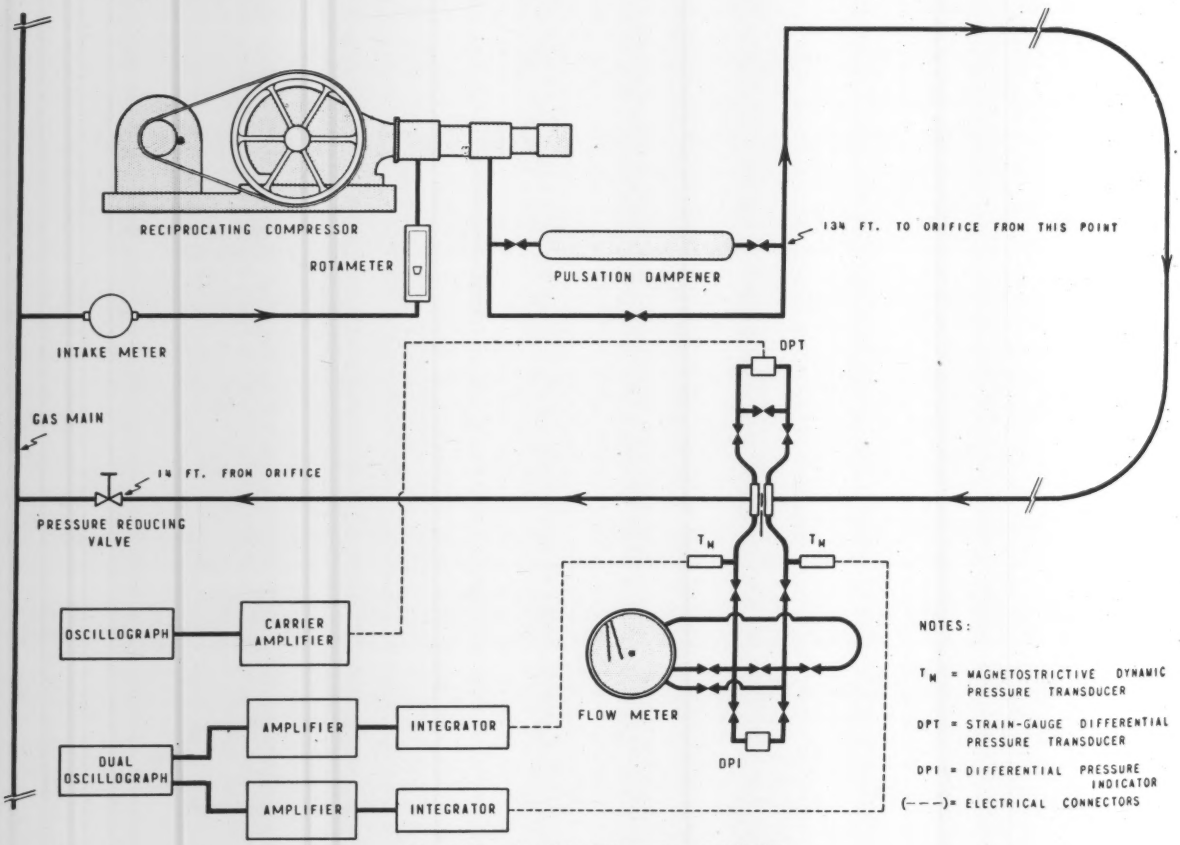

Fig. 6. Experimental orifice-meter installation.

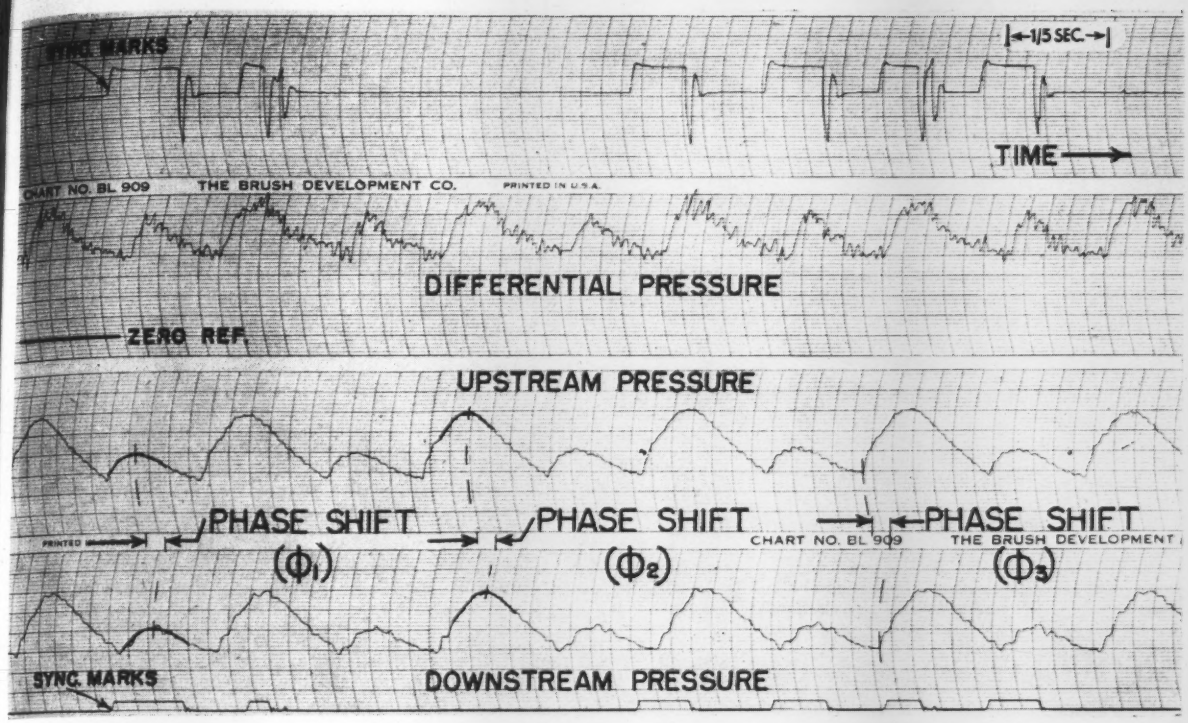

Fig. 7. Simultaneous traces of differential pressure, upstream pressure, and downstream pressure at an orifice plate.

TABLE I—PRESSURE-PULSE FREQUENCY-COMPONENT ANALYSIS UPSTREAM AND DOWNSTREAM OF ORIFICE FIELD EXPERIMENT

(Upstream and downstream levels are not comparable from the standpoint of intensity)

Compressor Located Downstream of Orifice

	*Intensity**	
Frequency (cps)	*Upstream (%)*	*Downstream (%)*
5.0	100	100
10.0	11	3
12.5	.	1
15.0	15	5
20.0	1	.
25.0	2	2
30.0	3	2
40.0	6	5
45.0	1	.
60.0	.	10
87.0	9	6
184	1	.
243	2	.
355	.	7
420	2	.

Boundary Conditions

16" meter run (I.D. = 15.25") w/10.5" plate

Pressure drop	= 35" H_2O
Pressure	= 478 PSIG
Throughput	= 3,460,000 SCFH
Temperature	= 86°F
Gas gravity	= 0.655

* 100% = strongest component of either upstream or downstream pulse

that a considerable change in pulse waveshape occurred from one side of the orifice to the other. This change was verified by comparison of oscillographic pulsation traces, which also showed the presence of phase shift between upstream and downstream waves.

A badly resonant condition in the flow-meter connecting lines to one of the meter runs was observed at the Blythe Station. With the pressure transducers located at the meter, resonant conditions were clearly demonstrated. Upon the insertion of a 25-foot length of ⅛-in. diameter copper tubing in one of the meter leads near the orifice-plate flange tap, a completely different picture with respect to instantaneous pulse pressures and differential at the meter was obtained; the resonant conditions were virtually eliminated. This change was explained as being due to one or both of two causes. One cause was that an unbalance in the acoustical length of the metering lines had been produced, thus altering the phase relationship of the pressure pulses reaching the recording meter through the lines. The second was in the relative increase in attenuation of pressure pulses in one of the leads due to the ⅛-in. diameter restriction. The net result clearly demonstrated the profound effect that acoustical changes in meter connecting lines can have on the operation of the inferential measuring type of recording flow-meter. It is believed that as a routine precaution, acoustical isolation of recording meters and/or their connecting leads would be of great benefit. Such isolation could readily be achieved by the use of acoustical filters[6] without resorting to methods of flow restriction, which may or may not retain adjustment over long periods of time.

Fig. 6 illustrates an experimental orifice located in a pilot-plant installation. Figs. 7 and 8 show the effect of pulsative flow in the installation shown in Fig. 6. Throughput settings were accurately reproducible from run to run by the use of a rotameter on the suction side of the reciprocating compressor. In order to compare the effect of pulsative with non-pulsative flow, a filter-type pulsation dampener was used. The dampener could be inserted in the flow path at will to remove nearly 100 percent of the pulsation induced by the compressor. Fig. 7 is a typical electronic trace of some of the recordings. Of immediate interest is the phase shift which occurs across the orifice. Phase shift Φ_1, Φ_2, or Φ_3, which are approximately equal, was established for corresponding portions of the pulse waves upstream and downstream of the orifice (at flange taps). The explanation for the alternating amplitudes of successive pressure waves is that the compressor is double-acting and the crank end stroke has less capacity than that of the head end. Note also that there is a considerable change in waveshape across the orifice.

The frequency-component analysis of the upstream and downstream waves is presented in Table II. The conditions under which these frequency analyses were obtained correspond to an attenuation in peak pulse of 39 percent (see Fig. 8). The variation in relative attenuations of the component frequencies is clearly illustrated in the 4th column of Table II, which shows the change in the percent intensity from a particular frequency component from upstream to downstream side of the orifice. These data are similar to those presented in Table 1 except that in this case all intensity figures are comparable with each other.

Fig. 8 illustrates the effect of pulsative flow on the flow rate indicated by a standard-type flow-meter for the above experiment. In determining the

TABLE II—PRESSURE-PULSE FREQUENCY-COMPONENT ANALYSIS UPSTREAM AND DOWNSTREAM OF ORIFICE LABORATORY EXPERIMENT

Compressor Located Upstream of Orifice

Frequency (cps)	*Intensity** *Upstream* (%)	*Downstream* (%)	*Change* (%)
2.2	23	17	— 26
4.4	100	70	— 30
6.6	23	12	— 48
8.8	20	6	— 70
11.0	18	3	— 83
13.2	4	1	— 75
15.4	10	2	— 80
17.6	3	2	— 33
19.8	10	3	— 70
22.0	4	3	— 25
24.2	4	2	— 50
26.4	5	3	— 40
28.6	7	2	— 71
30.8	4	2	— 50
33.0	3	2	— 33
35.2	5	3	— 40
37.4	3	2	— 33
39.6	3	2	— 33
41.8	4	2	— 50
44.0	3	2	— 33
60	5	2	— 40
75	3	3	0
100	3	2	— 33
120	3	1	— 66
200	3	1	— 66
250	3	1	— 66
400	2	1	— 50
750	2	0	—100

Boundary Conditions

½" meter run (I.D. = 0.620") w/0.202" plate
Pressure drop = 93" H_2O
Pressure = 200 PSIG
Throughput = 1573 SCFH
Temperature = 74°F., approximately
Gas gravity = 0.65

* 100% = strongest component for both pulses

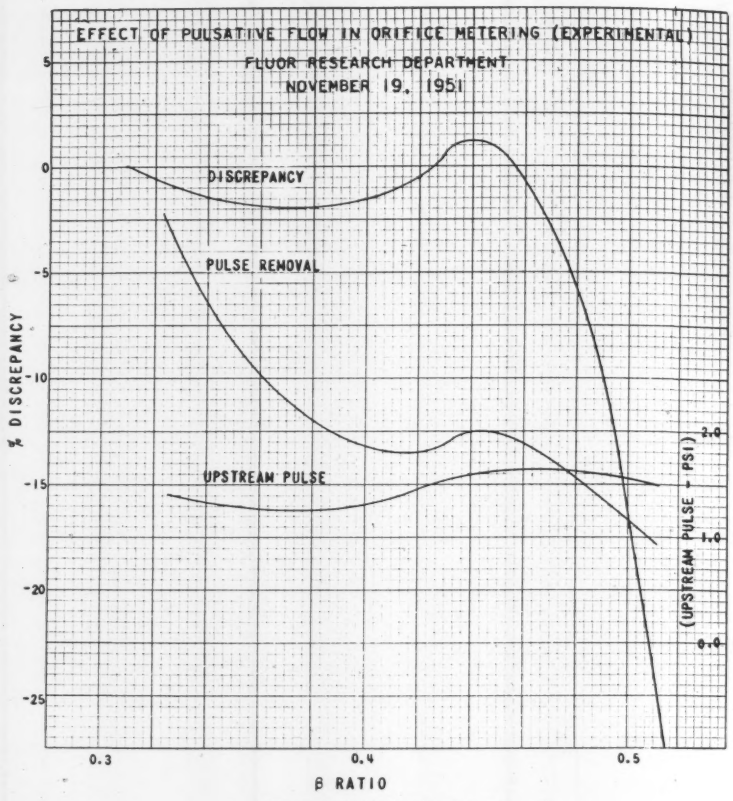

Fig. 8. Effect of pulsative flow.

percent discrepancy in indicated flow rate, flow-meter readings under conditions of no pulsation were assumed to be accurate. Removal of the pulsation dampener from the flow path, thus allowing pulsative flow to affect the orifice differential, resulted in changes in flow-meter readings. These changes in reading then were expressed as a percent of that obtained under smooth-flow conditions and plotted in Fig. 8 as percent discrepancy. The other curves of Fig. 8 are (a) the actual peak pulse pressure, and (b) the percent attenuation of the pulsation across the orifice. A good correlation is apparent between the latter and the percent-discrepancy curve.

To summarize, the objective of this article is to introduce electrical analogies into the orifice-metering problem, coupled with a sample of field and laboratory experimental data with the suggestion that the concept of analogies be used to help analyze the orifice-metering problem as caused by pulsative flow. The general theory evolved from this approach has been qualitatively substantiated by means of both field and laboratory experimental data. It is believed that a fundamental study of the dynamic relationship between flow rate and instantaneous pressure distribution in the vicinity of the orifice plate is necessary to the development of an orifice meter which is reliable under all flow conditions. The most obvious and direct way to solve the problem is, of course, to eliminate pulsative flow itself. It is believed that this can be done effectively, in most cases, by the use of filter-type pulsation dampeners. However, under the high-pressure conditions normally encountered in pipe-line gas transmission where an orifice flow meter might be operating on 800-psi. service with a differential pressure measured in inches of water, the presence of an otherwise insignificant pulsation might cause a profound effect on the flow-meter reading. To minimize the acoustical effects on inferential measurement by flow-meter leads and chambers without resorting to restrictions inserted in the leads themselves, effective isolation from resonant pressure variations in the vicinity of the orifice can be achieved by acoustical filters inserted in the meter leads close to the orifice take-off points.

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(15) "Pulsation and Its Effect on Flow Meters," Eric J. Lindahl, Associate Professor of Mechanical Engineering, The Ohio State University, Columbus, Ohio.

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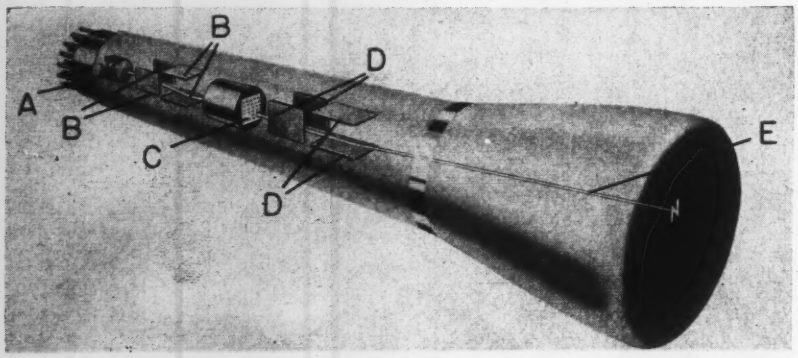


Fig. 1. The "Charactron": A, electron gun; B, deflection system for selecting matrix character; C, matrix; D, deflection system for positioning character; E, beam of electrons shaped by matrix.

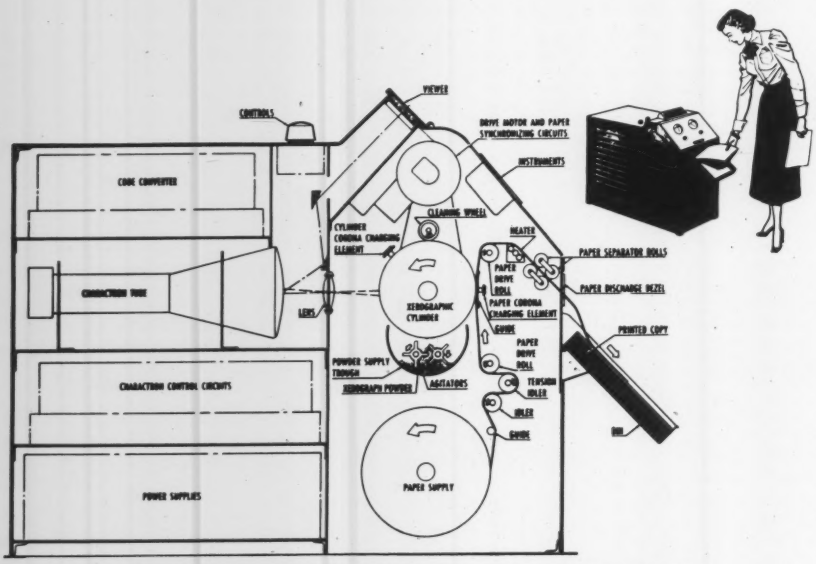


Fig. 2. "Charactron" combined with Xerographic printing equipment.

Instrument Courses

Fischer & Porter

The Fischer & Porter Company announces that its next instrumentation course will be held at the Hatboro, Pennsylvania plant, May 12 through 16, 1952. This course will cover manufacture, calibration, installation, operation and maintenance of primary and secondary process-control instruments. Details can be obtained by writing to the Fischer & Porter Co., East County Line Road, Hatboro, Pa.

Philips' Diffraction School

The North American Philips Company, Inc., Research and Control Instruments Division, 750 South Fulton Avenue, Mount Vernon, New York, announces its Spring (1952) X-Ray Diffraction School. Lectures and laboratory course have been arranged for April 21-25.

M. I. T.

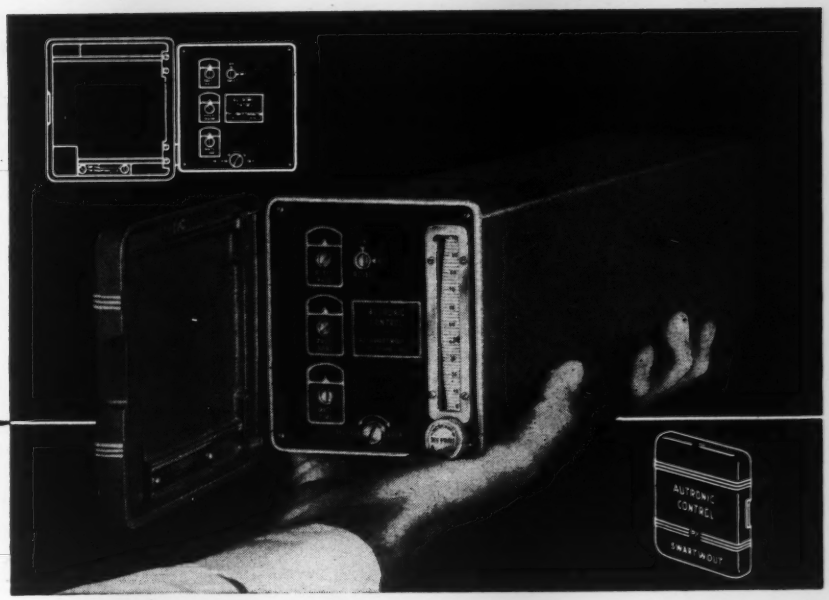
Two one-week specialized training programs in Instrumental Analysis will be offered from August 18 to 22 and from August 25 to 29 as part of the 1952 Summer Session at the Massachusetts Institute of Technology. The courses are planned to enable chemists from industrial and governmental laboratories to study the applications of new instrumental techniques and methods in the field of applied analytical chemistry, including potentiometry, polarography, conductimetry, amperometric titrations, applications of self-balancing recording potentiometers, spectrophotometry (visible and ultraviolet), colorimetry, fluorimetry, turbidimetry, nephelometry, photometric titrations, and flame photometry.

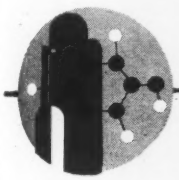
Infrared Spectroscopy

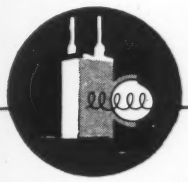
A special program in Infrared Spectroscopy will be given from June 16 to June 27 during the 1952 Summer Session at the Massachusetts Institute of Technology. The program is designed for those interested in the use of infrared spectra in the solution of chemical problems.

Boston College

Boston College has announced a special two-week intensive course in Modern Industrial Spectrography at Chestnut Hill, Boston, Massachusetts, from July 21 to August 1. The course is particularly designed for chemists and physicists from industries in the process of installing spectrographic equipment. Information on the course can







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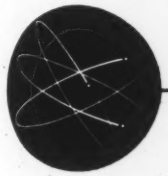

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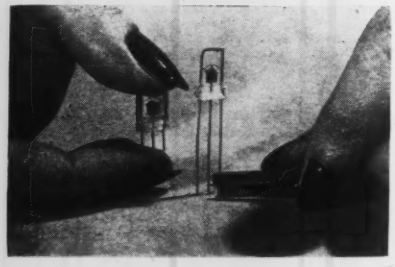
be obtained from Professor James J. Devlin, S.J. Physics Department, Boston College, Chestnut Hill 67, Boston, Massachusetts.

New Transistors

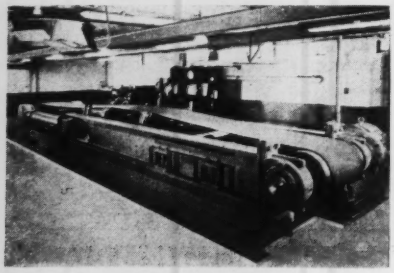
CAMDEN, N. J.—A new transistor has been unveiled by the Radio Corporation of America, in its first public disclosure of recent work on this important new electronic tool. An outstanding feature of the new transistor, according to RCA, is its greater reliability and ruggedness. It is shock resistant, unaffected by dampness, capable of being stored at elevated temperatures for long periods, and able to operate at temperatures as low as liquid air (−180 deg. C.) These characteristics have been achieved by embedding the elements of the transistor in a thermosetting resin to provide the finished product with a virtually indestructible protective case.

The transistor is a small semiconductor (germanium) in which current flow can be controlled by two fine wires that make point contact with the germanium. Their outstanding advantages are long life, small size, low power requirement, and no filament. Present disadvantages are temperature sensitivity and frequency limitations.



Conveyor-belt Tester

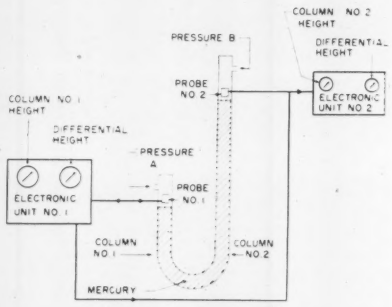
PASSAIC, N. J.—World's largest conveyor-belt testing machine, operating at Raybestos-Manhattan's laboratory at Passaic, N. J., the first machine of its kind, tests any 30-in. wide 80-ft. length of conveyor belt up to 200,000 lbs. total tension. Duplicates actual conveyor equipment arrangement of head, snub, bend, takeup, and tail pulleys with adjustable angle and elevation of troughing idler pulleys. Automatic recorders trace simultaneously, power input, stretch, tension, and speed at any speed up to 2,000 fpm.



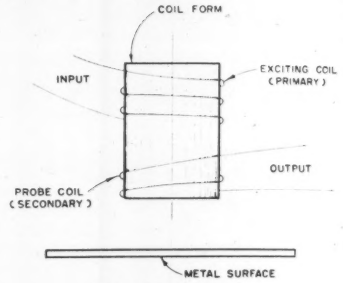
Manometer Height Sensing

WASHINGTON, D.C.—Differences in height between the two mercury columns of a mercury manometer are being determined with high precision by a new height-sensing technique developed by M. L. Greenough and W. E. Williams of the NBS electronic instrumentation laboratory, according to Technical Report 1620. Based on the use of high-frequency mutual-inductance probes, the method is sensitive to height changes of as little as 0.0005 inch. It also has the advantage of not requiring direct visual observation of the mercury surfaces; the mercury columns need not have transparent windows, and readings can be made at a distance. Since no float or electrical contact is required, disturbance of the mercury surface is minimized.

Above the mercury surface in each column is mounted a mutual-inductance probe consisting of a primary and a secondary coil. When the primary coil is supplied with constant radio-frequency current, the voltage induced in the secondary varies with the mutual inductance, or coupling, between the two coils. The mutual inductance, in turn, varies with the proximity of the mercury surface; the closer the mercury surface is to the probe, the greater is its shielding effect, and the less the output voltage. The output voltage thus becomes an index of probe-to-mercury distance, and can be used to indicate this distance with high precision.



Height-sensing system



Height-sensing pickup

Oscillograph Beam Intensification

WASHINGTON, D.C.—A new technique developed by J. H. Park of the National Bureau of Standards increases the "writing speed" of a high-voltage oscillograph to three-fourths the velocity of light, according to Technical Report 1586. High intensification of the electron beam is obtained momentarily by superposing a steeply rising voltage pulse on the steady voltage applied to the discharge tube of the oscillograph. The resultant increase in the intensity of the trace makes writing speeds up to 9100 inches per microsecond visible. A momentary pulse having a peak value of about 2,000 volts is superposed on the steady d-c voltage of 50 kv. normally applied to the discharge tube. This sudden change in voltage, although it is only 2 percent of the steady voltage across the discharge tube, momentarily disrupts equilibrium conditions in the tube, producing a greatly intensified electron beam for about 2 usec.

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SERVOMECHANISM

Continued from page 459

amplitude of the command and output signals.

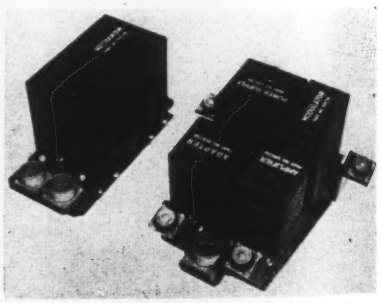
Command Transducer

In servo terminology, the process monitoring element, or "pickup," is referred to as a *command transducer*. The command transducer translates the physical quantity to which it is sensitive into a voltage. A large and growing number of devices designed for such service are appearing on the market. A brief list of typical devices which can perform as command transducers in a servo control system are: Synchros, pH meters, photocells, microphones, strain-gages, bolometers, viscosimeters, colorimeters, magnetometers, pressure gages, flowmeters, tachometers, thermopiles, pyrometers, pirani-gages, nuclear counters, barometers, potentiometers, chronometers, etc.

Features

In the past it has been felt by some that electronic control systems are undesirable due to the installation, trouble-shooting, and maintenance problems associated with a large chassis packed with circuit components that are interconnected by a maze of soldered-in wiring. This objection is no longer valid. The important feature of modern electronic control systems is that they are assembled from generalized building-block plug-in packages assembled together and interconnected to form a simple position or velocity servomechanism, or a more elaborate control analog computer. The resulting advantages are (1) standard components can be manfactured in quantity, therefore lowering cost, (2) a system composed of such units can be widely dispersed or closely grouped on a chassis, depending on space available, (3) system trouble-shooting and maintenance times are reduced because, as in series-wired Christmas-tree light maintenance, one replaces the plug-in units one at a time until the malfunction is located and corrected, and (4) the maintenance training required for the human monitor is negligible.

Most large industries already are using automatic control. This is par-



A typical servomechanism assembly using plug-in packaged function units. This two-chassis arrangement is designed to fit in a particular space requirement.

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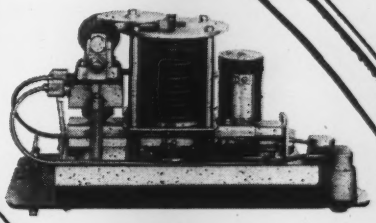
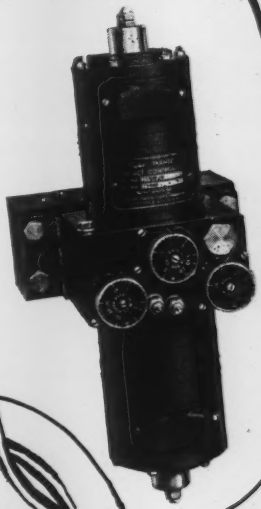
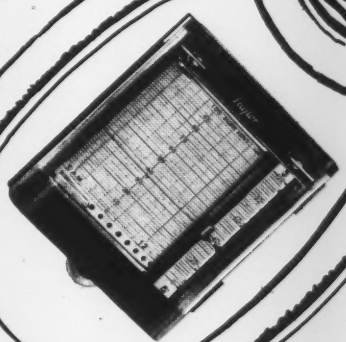


MEASURING? You'll want the greater accuracy for the vital first step in control given by Taylor TRANSAIRE* Transmitters. Temperature model has a new derivative action, SPEED-ACT*, in the measuring circuit that gives dynamic accuracy for changing temperatures. Transmitters detect changes of less than .1% of range span, are accurate to ½% of exceptionally short range spans available in both temperature and pressure models.



CONTROLLING? Taylor's TRI-ACT* Controller takes fullest advantage of TRANSAIRE* Transmitter's precision. A new control circuit embodies three control responses, proportional, PRE-ACT* (rate action) and automatic reset; with faster, more stable recovery on load changes, no overpeaking on startup.

RECORDING? The calibration accuracy of ½% of the range of the TRANSET* Recorder takes fullest advantage of the exceptionally high accuracy of the measuring and controlling units of the TRANSET System. Unique Roberts linkage system provides independent linearity, calibration and zero adjustments to assure highest accuracy. TRANSET Recorder is ideal for graphic panels, too; takes only 4⅜" x 5" panel space; uses a 30-day linear chart with 3 hours visible. Indicating receiver also available.



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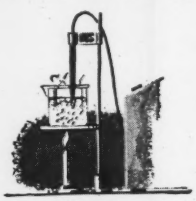

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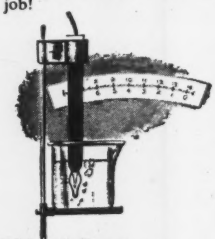

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ticularly true of the petroleum industry and portions of the chemical industry wherein the use of automatic control has been advanced by continuous process engineering. Even where the product is not readily adapted to continuous processing, automatic control of discrete steps in production is being instituted rapidly. Undoubtedly, the servomechanism, composed of plug-in components, will be a useful device in solving process control problems of the future.

PROCESS STABILITY

Continued from page 457

frequency is now at the higher value, F_2. As the amplitude around the loop at F_2 is less than unity, the system is stable. As the frequency goes higher and higher, the phase lag increases beyond minus 360 degrees and the loop amplitude approaches zero. Thus there is no chance at higher frequency of self-sustaining oscillation. As shown in Fig. 6, improvement in the dynamics of the regulator can contribute to the stability of the system. By improving the dynamics of the regulator it is possible to increase the gain, or sensitivity, of the regulator without causing instability. This leads to improved quality of control.

Behavior of Plant Under Automatic Control

By connecting V and V' in Fig. 4—that is, by closing the loop—control action is established. The complete system is shown in Fig. 7. A subtraction box, or differential, is inserted ahead of the regulator so that the desired value, or set point (W_S), can be stipulated.

One way of evaluating the effectiveness of the control system is to change the set point suddenly, and then watch the response of the plant output (W_o).

Fig. 8B shows the response of a plant under automatic control after a step change in W_S. The output rises, overshoots its final value, and oscillates several times before settling down. We can predict the overall response of the system to transients from frequency considerations.

Cut-off Frequency

In practice it is not desirable to have the amplitude close to unity at the point where the phase is minus 360 degrees. Likewise, it is not desirable to be near minus 360-degrees phase lag

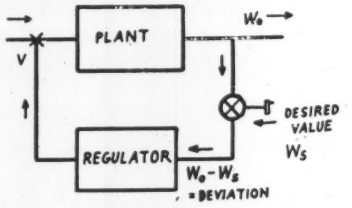

Fig. 7. Closed-loop control system with set-point adjustment.

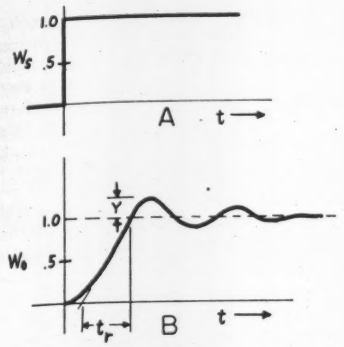

Fig. 8. Response of closed-loop system to step change in control point.

at the point where the amplitude is unity. A rule of thumb is that phase lag shall not be greater than 315 degrees at the point where the amplitude is equal to unity. (See Fig. 6.)

The *cut-off frequency* F^* is defined as the frequency at which the phase is 45 degrees above the minus 360-degree point—that is, where the phase is 315 degrees lagging (Fig. 6).

There are three approximate relations between frequency F^* and the shape of the transient curve in Fig. 8B. First, the rise time (T_R) of the transient is proportional to $1/F^*$. Thus, in order to get a short rise-time, the cut-off frequency should be as far to the right as possible. Second, the frequency of the oscillation superimposed on the transient is approximately equal to frequency F^*. Third, with the gain of the regulator set so that the amplitude response (H_1) is equal to unity at frequency F^*, the overshoot in the transient response (Y in Fig. 8) is approximately 3/10 of the ultimate step value. Thus, to a good approximation, the characteristics of the transient response can be inferred from the frequency-response diagrams.

Conclusions

From knowledge of plant response to step inputs, we can derive, qualitatively at least, the response of the plant to sinoidally varying inputs. The same procedure can be followed for the regulator. Regulator and plant then can be coupled together as a unit and can be described in terms of the overall open-loop phase shift and amplitude at all frequencies from zero to infinity. From the relation of amplitude and lag versus frequency in the range of significance, we can determine stability, and we can predict the character of a transient to be expected from a step input into the overall system. The frequency approach is invaluable in attacking problems of regulator design, particularly where computing functions are involved and where performances are to be improved by varying specific components. The dynamics of the regulator are as important to overall stability as are the dynamics of the plant. Therefore, a regulator with good dynamics—that is, with low phase shift

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at the frequencies of interest, provides superior overall control performance. A higher cut-off frequency is possible with such a regulator, and higher sensitivity is possible. Where high-performance control is desired on a given plant, a high-performance regulator is indicated. Hydraulic output stages in particular provide low phase shift over the frequency ranges of interest. Controllers employing long pneumatic impulse lines or long pneumatic actuator lines sometimes have poor dynamic performance and can restrict the overall loop behavior. The dynamic response in any specific instance can be obtained by plotting the frequency behavior, as in Figs. 5 and 6.

STANDARDIZATION

Continued from page 455

parisons based on a minimum of readily established reference data, rather than requiring reference to numerous equations, charts, nomographs, etc. These advantages more than justify this type of standardization even though the limitations must be recognized; for example, the over-simplification inherent in standard equations leads to excessive errors in cases of very low Reynolds numbers or in cases of compressible fluids undergoing large pressure drops across the valves. There is a need for more publicity on these limitations, as well as on the effects of body design factors in high-velocity flow applications.

Program Phases

Assuming that the need for standardization is universally recognized, the problem is how to accomplish it.

For an undertaking of this scope to gain a foothold, it must be spearheaded by a large organization. The Instrument Society of America is the logical one because it is the only national technical society devoted wholly to advancing the art and science of instrumentation.

The first phase would consist of gaining the whole-hearted support of the manufacturers. It is possible that the manufacturers might eventually, on a voluntary basis, accpet and act on the recommendations of a nationally recognized standards committee. However, attainment of stated objectives within a reasonable period of time might require action by some national government bureau concerned with defense mobilization.

The next phase in a program of this type would be the establishment of committees for setting up the standards to be followed in the instrument industry. There are several possible methods of approach to this problem; a logical one would be to use the Instrument Society of America's National Recommended Practices Committee. This committee, at present, consists of eleven subcommittees; namely, Thermocouple and Thermocouple Extension Wire, Flow Meter Installation, Con-

trol Valve and By-Pass Installations, Instrumentation Flow Plan Symbols, Pneumatic Control Circuit Pressure Tests, Outside Instrument Protective Cabinets, Support and Protection of Instrument Piping, Mercury Handling, Instrumentation for Corrosive Services, and Recommended Practices for Head Meter Installation. Additional sub-committees would be required.

This plan has some faults which are immediately evident. First, these sub-committees would be operating only part-time, as they have in the past. The need for additional manpower on these subcommittees is brought out by the fact that during the present committee's life-time of several years, it has produced only a few papers on tentative recommended practices. The members are, of course, engaged in earning a living at other work. As the entire instrument industry suffers from a shortage of experienced instrument engineers and designers, most companies would be reluctant to release men for standards committee work. Engaging the services of competent industrial design engineers to help staff the project would partially alleviate the manpower shortage.

In contrast with the general status of instrument standardization, a few noteworthy efforts have been made. For example, as of June, 1950 the major control-valve manufacturers began furnishing control valves in accordance with standard face-to-face dimensions established through efforts of I.S.A. members and manufacturers' representatives, and which are expected to be adopted by the A.S.A. Although these standards do not cover valves of all commonly used sizes, types, and materials, the results of this cooperative effort should benefit industry. Illustrating further commendable efforts toward standardization, a symposium on standardization of thermocouple-wire specifications was held on June 19, 1951 under the sponsorship of the IAeS-ASME Joint Aviation Instruments Committee. Although the individual problems of the military group and process industries group were not reconciled to the etxent of tentatively adopting a common standard (such as NBS curve A1 for iron-constantan wire), significant progress was made toward defining the problems involved and recording the majority opinions as to the most practical end results to be sought.

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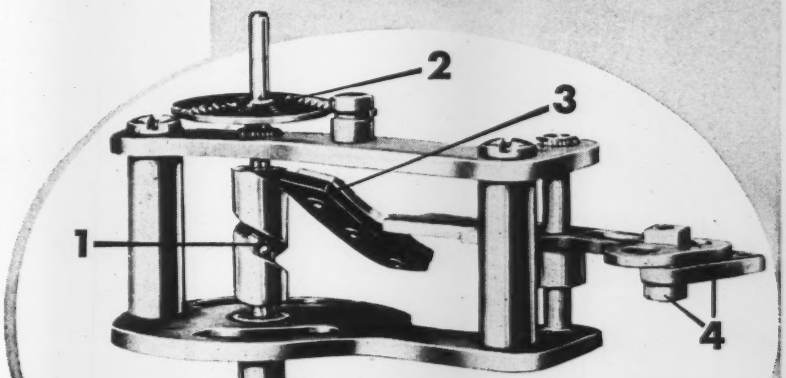

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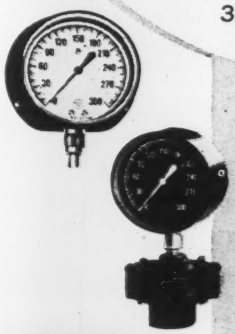

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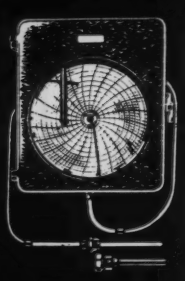

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Continued from page 461

equivalent to a negative change in grid potential. As a positive signal applied to the grid can not decrease plate current, the cathode potential cannot possibly increase more than the grid potential. Therefore the voltage gain of the stage, which is the ratio of cathode-signal voltage to grid-signal voltage cannot be greater than 1.

If the voltage gain were exactly 1, the cathode potential would follow the grid potential exactly. There would then be no change in grid-cathode potential during the signal and, therefore, no change in plate current. As there must be a change in plate current to produce a change in cathode potential, the cathode signal cannot be exactly equal to the grid signal. Therefore, as the cathode cannot change either more than or as much as the grid voltage, it must change by a smaller amount. This means that the output signal can be almost as large as the input signal, but not quite as large.

An approximate formula for the voltage amplification of a cathode follower is:

$$\textit{Voltage gain} = \mu/(\mu + 1),$$

where μ is the amplification factor of the tube. This equation shows that the voltage gain is usually about 0.8 or 0.9. In other words, the voltage of the output signal is slightly less than that of the input signal.

Output Impedance

An outstanding feature of the cathode follower is its low output impedance as compared to the output impedance of conventional voltage amplifiers. The output signal of a conventional voltage-amplifier tube is taken from the plate. Thus the impedance of the source of the signal is the plate resistance of the tube in parallel with the plate resistor. In conventional tubes this output impedance is from 5000 to 500,000 ohms. In cathode followers, however, the output impedance is the resistance of the cathode resistor in parallel with the plate resistance of the tube. As the cathode resistor can be less 1000 ohms, the output impedance usually is about 500 ohms.

The advantage of a low-impedance source of signal is that the signal can be used to operate instruments, such as milliameters, which require current. This cannot be done with a high-impedance source because the current taken by the meter causes a voltage drop across the internal impedance of the source, thus destroying the signal.

Another advantage of the relatively low output impedance of the cathode follower is that the shunting effect of the tube capacitance and wiring is reduced. This permits the tube to be operated at frequencies higher than conventional tubes.

As the cathode follower is used to supply currents rather than high voltages, it is commonly referred to as a current follower. It is essentially a power amplifier with no voltage gain.

Input Impedance

By definition, the impedance of a device is defined as the ratio of the voltage across it to the current through it. Thus the input impedance of a tube is the ratio of the signal applied to the grid to the current that flows to the grid.

In a conventional tube, the grid-cathode potential varies as the signal. Thus, on positive signals the grid goes more positive than the cathode and draws electrons from the cathode. In the cathode follower, however, the grid-cathode potential does not change much and there is very little current flow between the grid and cathode. Thus the input impedance of a cathode follower is much higher than that of a conventional voltage amplifier. For this reason a cathode follower has very little shunting effect on the preceding stage. Also, a number of cathode followers can be fed from a single source without shunting the source. The *electrometer*, which is a tube designed to have exceedingly high input impedance, is described later.

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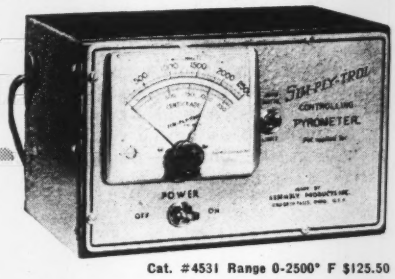

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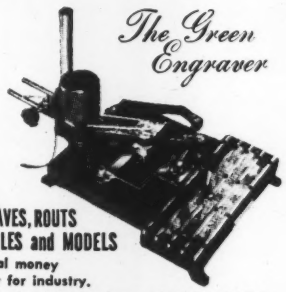

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can be applied to the grid because on positive swings the grid draws current and on negative swings the grid cuts off the plate current completely (Fig. 8-3). Therefore, such tubes usually can handle only signals of less than 5 volts. As the grid-cathode potential of the cathode follower does not change much when a signal is applied, the cathode follower can handle signals of greater amplitude. For example, assume that the no-signal bias of the stage in Fig. 8-16 is 14 volts. A grid signal of 15 volts causes the cathode potential to swing 12 volts more positive and 12 volts more negative. Thus the output signal can be 24 volts (peak-to-peak), whereas the bias changes by only 3 volts.

Polarity

The cathode potential of a cathode follower follows the grid potential. Thus the polarity of the output signal is the same as that of the input. This is in contrast to conventional voltage amplifiers in which the output plate signal is 180 degrees out of phase with the grid signal.

Uses

The high input impedance of the cathode follower is used to receive signals from high-impedance pickups, such as piezoelectric crystals. It is used also to connect several tubes to one source; even many cathode followers do not require much driving current.

The low output impedance is used to drive indicating and recording devices, power-amplifier stages, transmission lines, or any device requiring a low-impedance source. Thus the cathode follower is essentially an impedance-matching device. It is a power amplifier with no voltage gain.

Electrometer Tubes

The term "electrometer" applies to any instrument that measures voltages by means of electrostatic forces exerted between charged bodies. An electrometer can be a calibrated electroscope or a special vacuum tube designed for the purpose.

The outstanding feature of the electrometer is high input impedance—that is, the device drains very little current from the source of voltage being measured.

An ordinary vacuum tube can measure voltage by applying the unknown voltage to the grid and measuring the plate current. However, as the grid draws some current (in the order of microamperes), the input impedance is not high enough for many applications, such as radiation measurements.

The cathode follower has higher input impedance than a conventional amplifier, but still not high enough for some measurements.

The *electrometer tube* is a tube specially designed to have low grid current and hence high input impedance. The grid current of the electrometer tube is kept low by using (1) a very good vacuum in the envelope, (2) low electrode potentials to minimize gas ionization, (3) low cathode emission current, and (4) proper grid potentials to assure that the cathode emission all goes to the plate. The tube is operated in darkness to minimize photo emission from the grid, and the glass envelope is treated to keep its resistance high. With these precautions, grid currents as low as 10^{-17} ampere can be achieved.

Decoupling

The internal resistance of the power supply is an important factor. Every source of power has some internal resistance. This resistance acts like a resistance in series with the equipment to which the supply is connected. When current flows to the load, an unwanted voltage drop develops across the resistance. Furthermore, any change in load current causes a change in voltage which is transmitted to every tube connected to the supply. This is a common source of oscillation in multi-stage amplifiers. The oscillations produced because of the resistance of the supply can be of any frequency from a fraction of a cycle per second (motorboating) to megacycles per second, depending on the distributed parameters entering into the oscillation.

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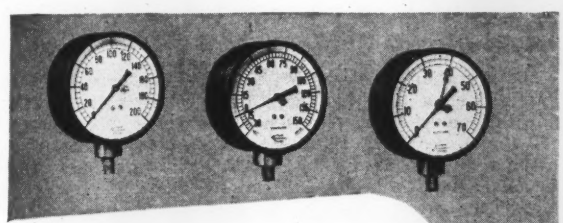

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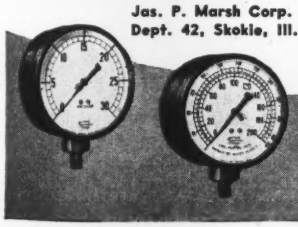

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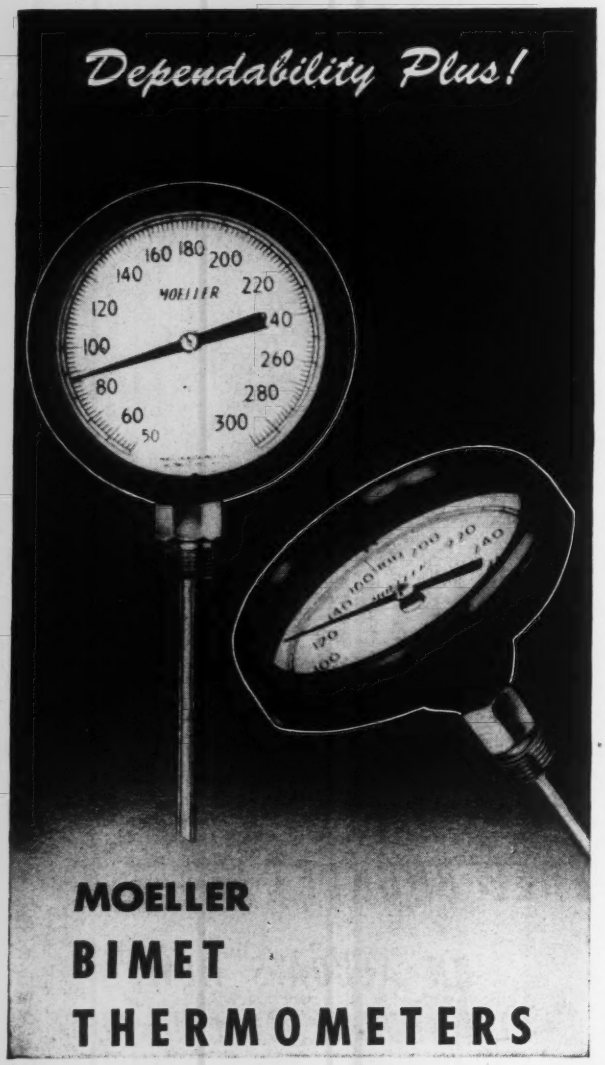

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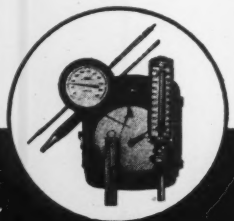

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coupling the signal from the power supply. The decoupling is accomplished by resistor R_4 and capacitor C_3 in Fig. 8-6. Any current variation in the tube is bypassed to ground through capacitor C_3 before the change reaches the B supply. Similarly, a change in the voltage of the supply is bypassed to ground before it reaches the tube. The junction of C_3 and R_4 in the figure is the effective source of B voltage for the stage. The time constant (R_4C_3) determines the lowest frequency which is decoupled by the decoupling arrangement. Decoupling is extensively used to confine a-c. signals to individual circuits and thus prevent oscillation.

Note that the decoupling network in Fig. 8-6 and the low-frequency compensation network in Fig. 8-11 are identical except for the values of R and C. In Fig. 8-6 a capacitor of low reactance to low-frequency signals is chosen. The capacitor C_f in Fig. 8-11 is chosen to have high reactance to low-frequency signals.

Note also that the decoupling network acts in both directions. It prevents signal variations at the plate of the tube from reaching the B supply, and it also prevents any rapid variations that do reach the supply from reaching the plate of other tubes with decoupling networks.

Noise

Electronic amplifiers always have some output noise, even when the input is shorted to ground. Such output is referred to as hum, microphonic noise, component noise, or electron-movement noise.

Hum

Hum is the result of induction from neighboring wires and circuits carrying 60-cycle alternating current. The sources of hum are stray magnetic and electric fields, 60-cycle alternating current in heaters and filaments of tubes, and improperly filtered power-supply systems. Shielding and care in placement of components and wires are used to prevent induction by way of the stray fields. Proper design of power supply and filament supply as well as proper choice of tubes is used to reduce hum from other sources.

Microphonic Noise

The vibration of elements in a tube causes microphonic noise. When a tube is jarred the electrodes vibrate. The vibration causes audio-frequency changes in plate current. The audio-frequency signals thus produced are amplified in the amplifier stages. The electrode vibrations also change the characteristic response of radio-frequency stages and permit the noises to be modulated on a radio-frequency signal.

Microphonic noise can be reduced by shock mounting the chassis or tubes to prevent vibration from reaching the tube electrodes. As microphonic effect varies from tube to tube of the same type, a different tube of the same type may be less microphonic. Non-microphonic tubes with rigid internal structure are available for special applications.

Component Noise

Irregular sizzling, frying, or crackling sounds may be caused by components of the receiver. One source of this noise may be faulty components—that is, poor contacts, faulty resistances, failing capacitors, or exhausted batteries.

Carbon resistors carrying direct current can be a source of component noise. Carbon-resistor noise is caused by changes in the contact resistance between adjacent granules in the crystalline carbon structure and is substantially uniform throughout the audio- and radio-frequency spectrum.

Electron-movement Noises

In addition to the noise that may be developed by faulty components, there are noises developed by electron movement in normal components. These noises are called shot effect, flicker effect, positive-ion noise, and thermal agitation. Noises produced by electron motion set the ultimate

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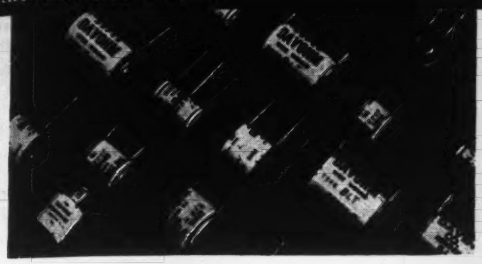

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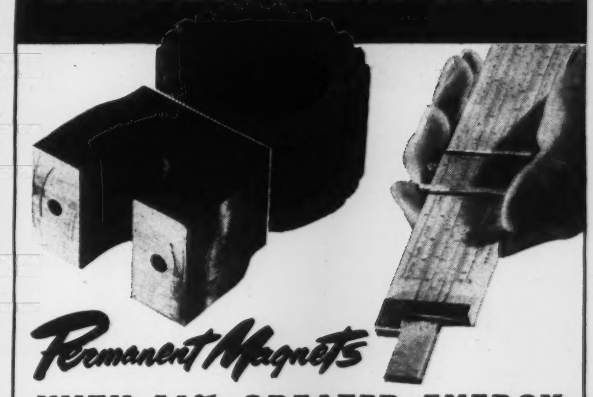

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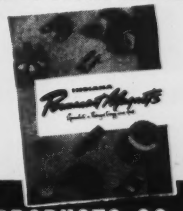

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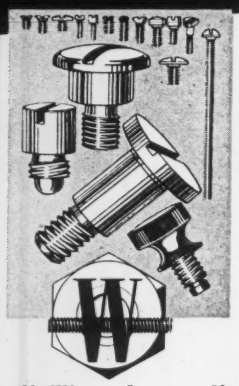

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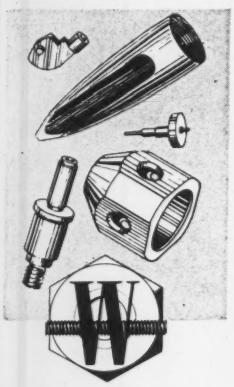

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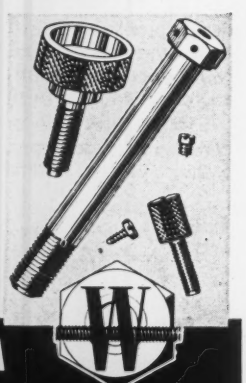

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limit to the sensitivity that may be built into an amplifier because the motion is common to all matter and little can be done to reduce the effect. The amount of all these types of noise developed by electron motion is fairly uniform over the entire audio and radio portion of the frequency spectrum.

Shot-effect noise results from the fact that the stream of electrons flowing from the cathode to the plate of the vacuum tube is made up of a series of particles rather than a continuous fluid. The electron flow resemble hailstones striking the metallic plate. This discontinuous flow gives rise to small irregularities in plate current of the tube which, when amplified, add to the noise level. As the space charge in the tube tends to smooth out the irregularities in the arrival of electrons at the plate, the emission of electrons from the cathode should be sufficient to produce an adequate space charge. One way in which to increase the space charge is to increase the temperature of the cathode.

Flicker-effect noise is a form of shot effect caused by changes of emission over small cathode areas. Oxide-coated filaments are susceptible to this type noise.

Positive-ion noise is a form of shot effect caused by the ionization of residual gas in the tube, or by positive-ion emission by the cathode. Tungsten filaments are common sources of this type noise.

The most important noise developed internally by electron motion arises from thermal agitation of electrons in the conductors in the input circuit. This is because the noise at the input is amplified the most. The motion of electrons in any conductor is not uniform; although the predominant motion depends on the temperature and the applied voltage, some electrons move faster and some slower. The predominant motion of the electrons is the desired current, but irregular instantaneous noise voltages also are developed because of the random motion of many of the free electrons. The energy of this type of noise is uniformly distributed over the entire frequency spectrum from zero frequency to many megacycles per second. Thus, the magnitude of the noise produced on frequencies between 1,000 and 2,000 cycles is the same as that produced on frequencies between 1,000,000 and 1,001,000 cycles.

Thermal agitation and shot effect are the limiting factors to the sensitivity that may be built into an amplifier. The noise voltages from these sources set a limit to the lowest signal voltage that can be amplified without being lost in a background of noise. An idea of the order of magnitude of this limit can be obtained by noting that the thermal-agitation noise developed by a ½-megohm resistor, at room temperature, for a frequency band 5,000 cycles wide, is 6.4 microvolts. This voltage is independent of the resistor material and would be developed across the most noise-free resistor available. A ½-megohm carbon resistor would develop not only 6.4 microvolts of thermal-agitation noise, but also a larger noise voltage produced by the irregular granular contacts.

TEST ITEMS—VIII. AMPLIFIER CIRCUITS—(Part 2)

8-24. A low-frequency compensation capacitor in the plate circuit of a stage should have
(a) equal reactance at all frequencies
(b) low reactance at low frequencies
(c) high reactance at low frequencies
(d) high reactance at high frequencies

8-25. High-frequency compensation usually is done by
(a) compensation coils
(b) compensation capacitors
(c) compensation resistors
(d) all the above

8-26. The advantage of fixed bias is that it
(a) requires only a resistor and a capacitor
(b) depends on plate current
(c) provides constant bias
(d) requires no external voltage

8-27. The most common method for providing bias is
(a) fixed bias
(b) cathode bias
(c) grid-leak bias
(d) plate bias

8-28. The reactance of the capacitor that shunts a cathode-bias resistor should be about
(a) 10 times the resistance at the highest signal frequency
(b) 10 times the resistance at the lowest signal frequency
(c) one tenth the resistance at the highest signal frequency
(d) one tenth the resistance at the lowest signal frequency

8-29. Grid-leak bias has the disadvantage of
(a) requiring a resistor and a capacitor
(b) requiring a compensating inductor
(c) depending on signal voltage
(d) depending on plate current

8-30. Degenerative feedback is characterized by
(a) in-phase feedback
(b) increased distortion

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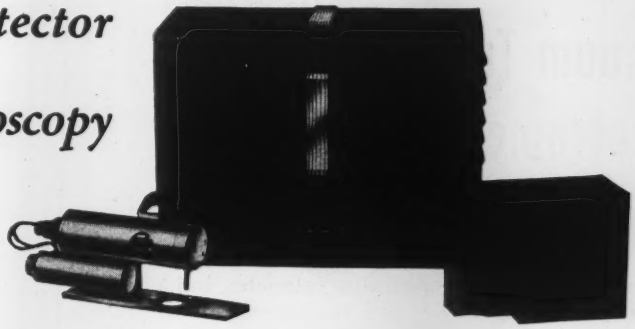

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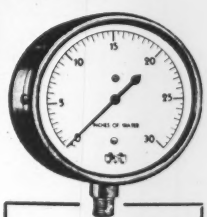

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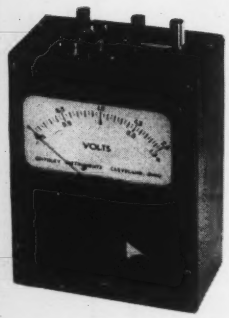
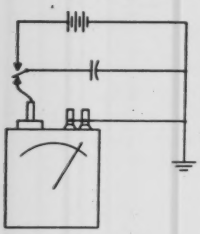
New Vacuum Tube Electrometer has many uses



Here is an exceptionally versatile dc voltmeter, and a few of its many uses. The Keithley Instruments Model 200 Electrometer has an input resistance of over 10^{14} ohms shunted by 6 mmf; 2 and 20 volt scales, with input currents of 5×10^{-14} and 5×10^{-13} ampere respectively. Accuracy is within 2% full scale, or within 5% of the reading at low values.



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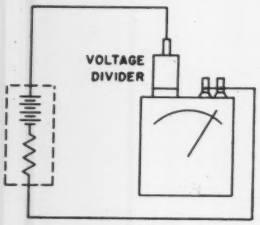
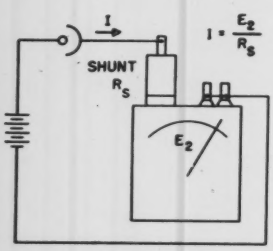
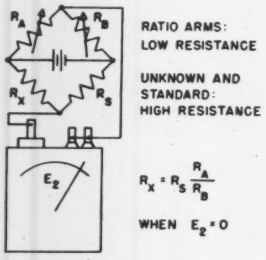
Model 2002 Voltage Divider has 100 : 1 ratio, clips over guard ring of HI terminal. Thus, dc circuit potentials up to 500 volts, such as the open circuit voltage of this high impedance source, are read directly.





CURRENTS AS LOW AS 10^{-14} ampere are measured directly from Model 2001 Electrometer shunts. Available with resistances from 1.0×10^6 up to 1.0×10^{12} ohms. Typical uses: photocell currents (shown), ion chambers, capacitor and insulation leakages.



RESISTANCES UP TO 10^{13} OHMS are easily measured with Wheatstone Bridge circuit diagramed, or by measuring current resulting from known applied voltage. Typical uses include: standardizing resistors, measuring insulation samples.

For complete literature on the Model 200 Electrometer, write —

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(c) oscillation
(d) reduced gain

8-31. Regenerative feedback is characterized by
(a) high stability
(b) in-phase feedback
(c) reduced gain
(d) reduced distortion

8-32. Which of the following provides degenerative feedback?
(a) A bypassed cathode resistor.
(b) An unbypassed cathode resistor.
(c) An in-phase feedback signal.
(d) A decoupling network.

8-33. The output of a cathode follower is taken from the
(a) plate
(b) grid
(c) cathode
(d) screen

8-34. The voltage gain of a cathode follower is
(a) less than one
(b) about 20
(c) the same as a triode amplifier
(d) the same as a pentode amplifier

8-35. The cathode follower is characterized by
(a) high input impedance
(b) low output impedance
(c) power gain
(d) all the above

8-36. A cathode follower can handle larger signals than a conventional amplifier because the
(a) bias is greater
(b) input impedance is higher
(c) output impedance is lower
(d) cathode follows the grid

8-37. The input impedance of a cathode follower is high because the
(a) bias is large
(b) cathode follows the grid
(c) output impedance is low
(d) gain is high

8-38. A decoupling network is used to
(a) couple cascade amplifier stages
(b) prevent signals from reaching the B supply
(c) keep the B supply from reacting to line changes
(d) all the above

8-39. Microphonic noise originates in
(a) vibration
(b) stray magnetic fields
(c) poor contacts
(d) all the above

8-40. The ultimate sensitivity of an amplifier is limited by
(a) microphonic noise
(b) hum noise
(c) electron-motion noise
(d) faulty components

ELECTROMETER APPLICATIONS

Continued from page 458

Potential Measurements

The electrometer can be used to measure many potentials encountered in engineering problems. Some typical applications are: (1) determining constants of *piezoelectric crystals;* (2) ascertaining the performance of charged *capacitors* or studying the absorption and residual potentials of the *dielectric;* (3) measuring voltages in *d-c. amplifiers* without producing small voltage changes in the first stages, which are greatly amplified in succeeding stages, or measuring continuously the grid-cathode potential in adjusting an amplifier circuit, (4) aligning *FM discriminators* under no-load conditions; and (5) detecting *electrostatic fields* to indicate the presence of charges on insulating surfaces, or on thread in a loom, or on paper in printing operations, etc.

Current Measurements

An electrometer shunt converts the instrument to a micromicroammeter by connecting a resistor across the input; values as high as 10^{12} ohms can be used. The combination measures smaller currents than most wall galvanometers, and with the advantage of a much shorter time constant than the mechanical system. A limitation in some circuits is the 0.5-volt drop required across the shunt resistor.

Important applications in which the high sensitivity and low periods of the electrometer can be used advantageously as a micromicroammeter are in measuring (1) *insulation leakage current*—by measuring the current through a known-sized sample of the test material, the resistance can be computed from the applied voltage and the current; from this the specific resistivity in ohm-cm. is computed; (2) *photocell currents*—in measuring low levels of illumination; (3) *ion-chamber current*—in measuring the amount of ionization produced by incident radiation; (4) *mass-spectrometer current*—in measuring ion masses; (5) *capacitor dielectric leakages*—in measuring the d-c. current flowing through a charged capacitor; and (6) *vacuum-tube grid currents*—in evaluating tube performance.

Capacitor Measurements

Capacitors can be analyzed quickly with the electrometer by measuring (1) *absorption and residual* potentials of the dielectric, as outlined previously; and (2) *leakage currents,* as shown in Fig. 2. This gives leakage current without the confusion of charging current. The technique is

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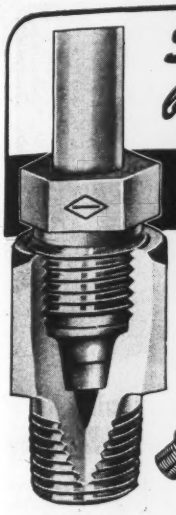

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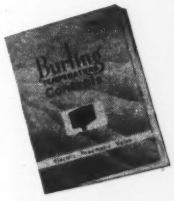

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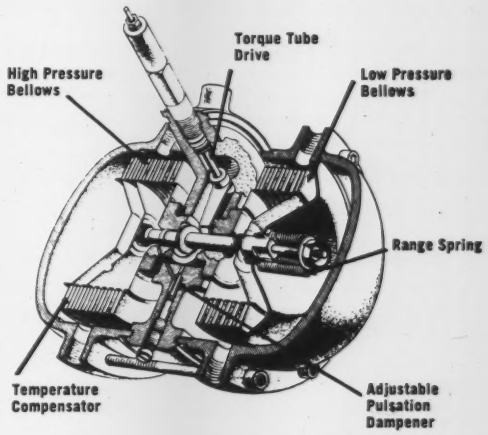

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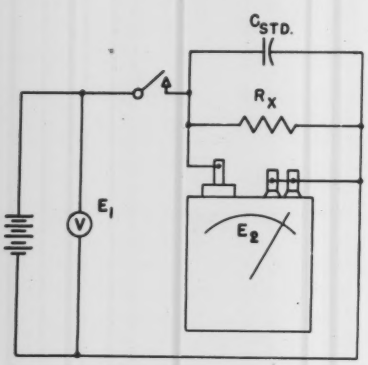


$$R_X = \frac{t}{C_{STD} \log_e \left(\frac{E_0}{E_t}\right)}$$

t = TIME IN SECONDS
$E_t = E_2$ AT TIME t
$E_0 = E_1 = E_2$ AT $t = 0$
R_X - OHMS
C_{STD} - FARADS

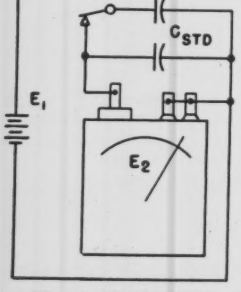
Fig. 2. Capacitor charge-decay circuit, for determining either R or C when other is known.

a rapid method of measuring the capacitor leakage, particularly when used with large capacitors which have small leakage. When capacitors have long time-constants, the terminal potentials can be measured periodically, thus eliminating drift error.

Capacitance can be measured by the interesting methods shown in Figs. 3 and 4. The method involves measuring an unknown capacitance when the known parameters are only one capacitor and the voltage measured with the electrometer; the equations illustrate the charge division when capacitors are connected in series or parallel.

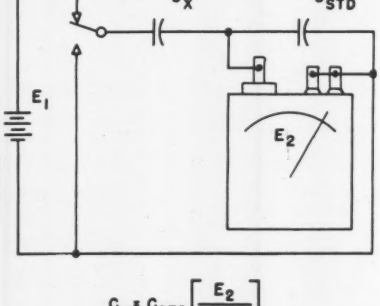
Capacitance can be measured also by the decay of charge in the circuit of Fig. 2. The known resistance is chosen smaller than the leakage resistance; the capacitance is the unknown parameter.

Integration is possible with a good capacitor and the electrometer, as shown in Fig. 5. If ion charges are accumulated by the capacitor, the voltage which the electrometer reads is proportional to the total charge—that is, the radiation dose.

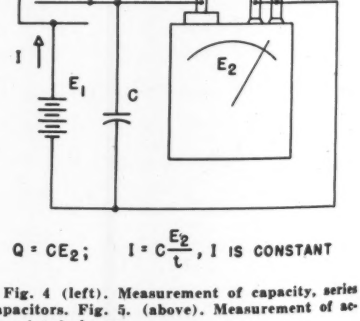


$$C_X = C_{STD}\left[\frac{E_2}{E_1 - E_2}\right]$$

Fig. 3. Measurement of capacity, parallel capacitors.



$$C_X = C_{STD}\left[\frac{E_2}{E_1 - E_2}\right]$$



$Q = CE_2$; $I = C\frac{E_2}{t}$, I IS CONSTANT

Fig. 4 (left). Measurement of capacity, series capacitors. Fig. 5. (above). Measurement of accumulated charge.

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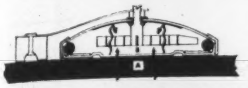

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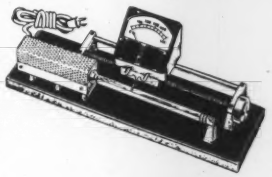

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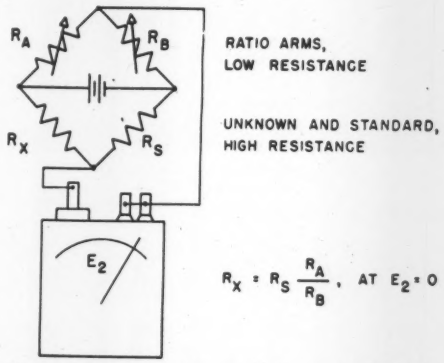

Fig. 6. Wheatstone bridge measurement of resistance.

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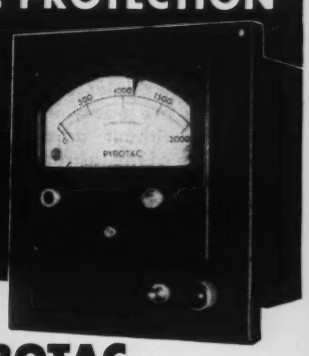

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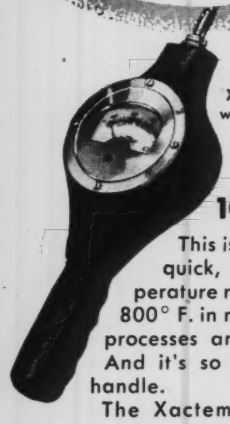

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Manufacturers' New Literature

In this department we report new literature, pertaining to instrumentation, received from the manufacturers. We urge readers to request ONLY those bulletins which will be of value to them. Use the Postage-free Order Card on Page 517.

Requests for literature FROM ABROAD should be made on company letterhead and mailed DIRECTLY to the manufacturers.

Temperature

U-280 **Resistance Thermometers.** 36-page Catalog EN-S4 describes in detail entire line of maker's "Thermohms," parts, and accessories. A 5-page tabular guide to selection for various applications describes how unit is used and where it is usually installed.—Leeds & Northrup Co., 4934 Stenton Ave., Phila. 44, Pa.

U-281 **Controlling Pyrometers.** 4-page Bulletin G-2 illustrates and describes maker's line of "Sym-Ply-Trol" indicating and controlling pyrometers. Includes features and applications.—Assembly Products, Inc., Chagrin Falls, Ohio.

U-282 **Test Chamber.** 4-page illustrated bulletin contains specifications, operating instructions, and principle of "Statham Model TC-1" test chamber that operates from −65 to +275 deg. F. —Statham Development Corp., 12411 W. Olympic Blvd., Los Angeles 64, Calif.

U-283 **Temperature, Air Velocity, and Dew Point.** 138-page indexed catalog contains maker's illustrated bulletins on industrial instruments, including pyrometers, resistance thermometers, temperature controllers, velometers, and dew-point indicators.—Illinois Testing Laboratories, Inc., 420 N. LaSalle, Chicago 10, Ill.

U-284 **Temperature Control.** 4-page illustrated Bulletin 2002 covers maker's "Pyrotac" designed to protect furnaces against excess temperature. Includes applications and features.—Illinois Testing Laboratories, Inc., 420 N. LaSalle St., Chicago 10, Ill.

U-285 **Low-temperature Research.** 4-page first issue of "Cold Facts" is informal presentation of current activities in liquid-helium temperature and electromagnetic research, featuring new techniques.—Arthur D. Little, Inc., 30 Memorial Drive, Cambridge 42, Mass.

Pressure

U-286 **Sensitive Altimeters.** 4-page Publication No. TP-24-A-1 describes three types of altimeters for surveyors and mappers.—Wallace & Tiernan Products, Inc., Belleville 9, N. J.

U-287 **Pressure Transducers and Accelerometers.** 58-page illustrated brochure "Statham Instruments" contains maker's bulletins and "Instrument Notes" on extensive line of pressure transducers, dynamometer pickups, accelerometers, etc. Includes principles, response characteristics, and detailed specifications.—Statham Laboratories, 12401 W. Olympic Blvd., Los Angeles 64, Calif.

Combustion

U-288 **Combustion Instruments.** 2-page illustrated Publication 52-949 contains brief descriptions of maker's large line of combustion controls, combustion instruments, flowmeters, draft gages, etc.—The Hays Corp., Michigan City, Ind.

U-289 **Combustion Control.** 24-page illustrated Bulletin 1023 contains diagrams and descriptions of nine typical firing methods and maker's sixteen major equipment components. Includes list of 300 applications.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

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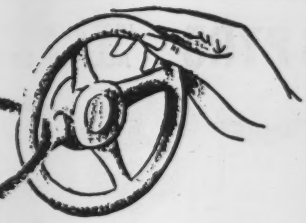

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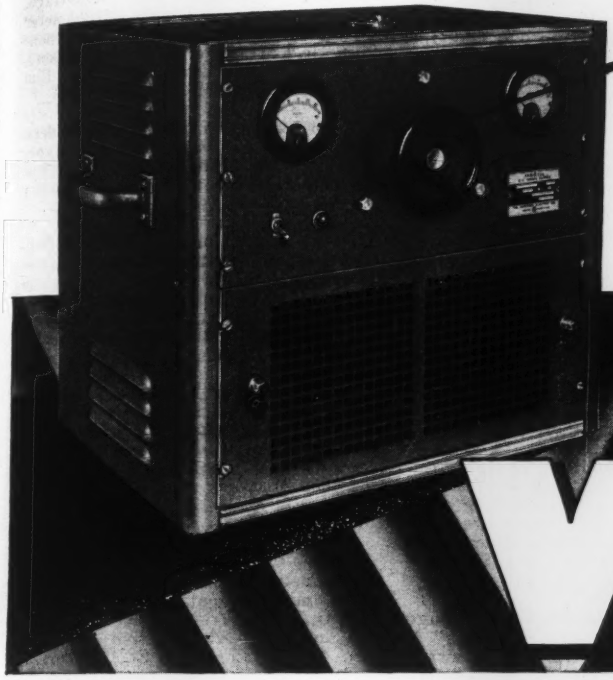

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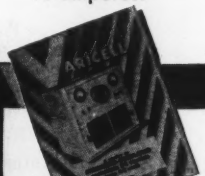

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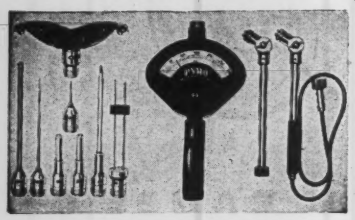

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NEW LITERATURE

U-290 **CO_2 Recorder.** 12-page illustrated Bulletin 51-1008 describes maker's "Condu-Therm" CO_2 recorder which uses thermal-conductivity principle of analysis. Includes features and operation.—The Hays Corp., Michigan City, Ind.

U-291 **Combustion Tester.** 4-page Form V7 illustrates and describes new combustion tester that indicates CO_2, temperature, and draft on one dial. Includes features and operation.—Victory Engineering Corp., 744 Broad St., Newark, N. J.

U-292 **Oxygen Indicator.** 4-page Bulletin Dw-4 illustrates and describes new "Type C-2" oxygen indicator that uses carbon electrode immersed in "Oxylite." Includes features, operation, and maintenance.—Mine Safety Appliance Co., Braddock, Thomas & Meade St., Pittsburgh 8, Penna.

U-293 **CO_2 Indicator.** 1-page announcement describes a portable analyzer for checking combustion efficiency.—Robert D. Richardson, R. 3, Box 345, Michigan City, Ind.

Recording

U-294 **Remote-writing System.** Legal-size folder contains several pieces of literature on new "Telescriber" system with "Insta-Forms" which are automatically ejected from receiver.—Tel-Autograph Corp., 16 W. 61st St., New York 23, N. Y.

U-295 **Draftsman's Stencils.** 20-page booklet on "Axonometric Drawing" is an educational presentation of drawing methods, supplemented by catalog descriptions of "Instrumaster" stencils.—John R. Cassell Co., 110 W. 42nd St., New York 18, N. Y.

U-296 **Rectilinear Recorders.** 1-page ad reprint describes inkless single- or multi-channel direct-writing recorders with high-torque movements.—Industrial Div., Sanborn Co., 39 Osborn St., Cambridge 39, Mass.

U-297 **Multi-speed Chart-drum Drive.** 2-page brochure contains reprint of article "Minute-to-Month Drives" by John Gorrell in *The Instrument Maker.* —Gorrell & Gorrell, Haworth, N. J.

U-298 **Drum-chart Recorders, Chart Papers, etc.** 64-page vest-pocket-size catalog describes recorders, electrical instruments, automatic timers, motors, supplies, etc.; contains samples of recording papers.—Gorrell & Gorrell, Haworth, N. J.

Inspection and Testing

U-299 **Dial-indicator Gages.** Pocket-size folder describes several models of "Geneva" machinists', tool makers' and inspectors' dial indicators.—Chicago Dial Indicator Co., 180 N. Wacker Dr. Chicago 6, Ill.

U-300 **Electronic Gaging.** 4-page illustrated bulletins cover maker's line of electronic gages, including "Indi-Ac" for general-purpose gaging, "Micro-Ac" electronic microcomparator, and "Par-Ac" electronic production gage. Includes features and specifications.—Graham-Mintel Instrument Co., 735 Carnegie Ave., Cleveland 15, Ohio.

U-301 **Washability and Abrasion Testing Machine.** 4-page bulletin describes new "Model 105" for paints, lacquers, and waxes, with controlled physical and time conditions.—Gardner Laboratory Inc., Bethesda 14, Md.

U-302 **Paint (etc.) Thickness Gage.** 4-page bulletin describes "Elcometer Dry Film Thickness Gage" for nonmagnetic coatings on magnetic surfaces. —Gardner Laboratory Inc., 4723 Elm St., Bethesda 14, Md.

U-303 **Abrasion Specimen Holders.** 6-page Bulletin 5105 describes ten types of holders for abrasion-test specimens. —Taber Instrument Corp., 111 Goundry St., North Tonawanda, N. Y.

U-304 **Insulation Tester.** 2-page Bulletin No. 60 illustrates and describes "Catalog No. 1070" direct-reading insulation tester using d.c. for testing motors, appliances, etc.—The Eastern Specialty Co., 3619 N. 8th St., Philadelphia 40, Pa.

U-305 **Coating Thickness Tester.** 1-page announcement describes instrument for measuring thickness of all common deposits on magnetic or nonmagnetic base metals.—Dep't I, Kocour Co., 4800 St. Louis Ave., Chicago 32, Ill.

Radioactivity

U-306 **Contamination Monitor.** 2-page illustrated brochure describes features and specifications of new "Raychronix Model D-3" surface-contamination monitor.—Radioactive Products, Inc., 443 W. Congress St., Detroit 26, Mich.

U-307 **Radioactivity Instruments.** 8-page brochure contains reprint "Instrumentation for Isotope Utilization," which describes basic radioactivity instruments.—Nuclear Instrument & Chemical Corp., 229 W. Erie St., Chicago 10, Ill.

Weight

U-308 **Light-projection-indication Scales.** 4-page Form 3201 describes six types of "Shadowgraph" scales in which the usual pointer is replaced by a projected shadow on an illuminated dial.—The Exact Weight Scale Co., Columbus 8, Ohio.

U-309 **Fan-dial Scales.** 4-page Form 3256 illustrates and describes a new line automatic pendulum-type scales with fan dials. Five types and 23 models. —The Exact Weight Scale Co., Columbus 8, Ohio.

U-310 **Conveyor Scale and Automatic Selector.** 4-page bulletin describes three models of "Selectrol" scales for automatically weighing and classifying. —The Exact Weight Scale Co., Columbus 8, Ohio.

Flow

U-311 **Controlled-volume Pump.** 24-page illustrated bulletin describes maker's line of "Pulsafeeder" piston-diaphragm pumps. Includes features, con-

struction, applications, and imposing list of chemicals handled.—Lapp Insulator Co., Inc., Process Equipment Div., LeRoy, N. Y.

Optical

U-312 **Stroboscopes.** 8-page Form 766-A explains how a stroboscope works and describes all of maker's stroboscopes.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-313 **Light Sources.** Pocket-size leaflet describes "Lindly" microscope lamps, bright-beam lamp, etc.—Gardner Laboratory, Bethesda 14, Md.

U-314 **Miniature Lamps.** 36-page catalog lists and illustrates hundreds of miniature lamps and their applications. —General Electric Lamp Division, Nela Park, Cleveland 12, Ohio.

Chemical

U-315 **Electrolytic Conductivity Curves.** 1-page Bulletin 4135D describes graphs of basic data on conductivity of various aqueous electrolytes in useful ranges of temperature and concentration.—Industrial Instruments, Inc., 17 Pollock Ave., Jersey City, N. J.

U-316 **Viscosimeters.** 4-page Bulletin 15 describes Cannon-Fenske and Ubbeholde viscosimeters carried in stock for 24-hour shipment.—Cannon Instrument Co., Box 812, State College, Penna.

U-317 **Spectrographic Analysis.** 4-page Vol. 4 No. 6 issue of "ARL Spectrographer's News Letter" features article on spectrographic analysis of zinc die-casting alloys and description of new integrator and focal-plane stepped sector.—Applied Research Laboratories, Glendale 5, Calif.

U-318 **Battery-water Units.** Pocket-size folder describes two models of "Hydrion" units for conversion of ordinary tap water to mineral-free battery water. —A. E. Tomkin & Co., 1828 Columbia Rd., N.W., Washington 9, D. C.

Air

U-319 **Air Cleaner and Dehydrator.** 2-page Bulletin B30 describes a new model of "Condensifilter" designed especially for instrument use, which combines dehydrator, filter and trap.—Hankison Corp., 1501 Beaver Ave., Pittsburgh 33, Pa.

U-320 **Dehumidification.** 20-page Bulletin 220 (price $1.50) is a technical article "Vapor Barriers for Dehumidification" by Professors E. R. Queer and E. R. McLaughlin.—Pittsburgh Lectrodryer Corp., P. O. Box 1766, Pittsburgh 30, Penna.

U-321 **Humidity Measurement.** 6-page Bulletin 2051 illustrates and describes maker's "Dewpointer" which measures dew point, vapor density, vapor pressure, etc. Includes principles and operation.—Illinois Testing Laboratories, Inc., 420 N. LaSalle St., Chicago 10, Ill.

U-322 **Vapor Adsorption.** 4-page Bulletin S-7.3 describes application of eight types of equipment to processing of liquids, air and other gases, including heating, dehumidifying, flow-measure-

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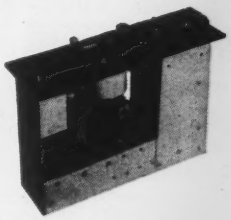

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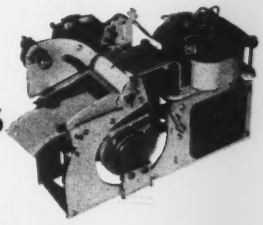

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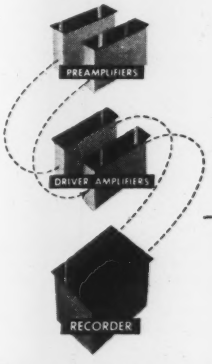
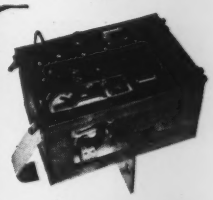


Any of the recording channels in the three systems at the right may include *either* a Strain Gage or General Purpose Amplifier, or the latter in combination (in 2-, and 4-channel systems) with either AC or DC Preamplifiers. For, any of the Amplifiers or Preamplifiers provided for in a system may be quickly *removed* from its place in the system and as quickly *replaced* with an alternate type.



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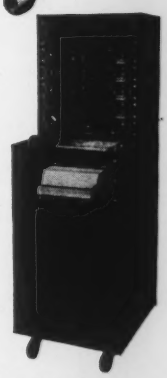

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NEW LITERATURE

ment, etc.—Selas Corp. of America, Phila., 34, Penna.

Process Control

U-323 **Process Control.** 28-page Fall 1951 issue of "Taylor Technology" features a 7-page article by Research Director W. I. Caldwell on a method of determining controller settings and process equipment design. Also articles on control of several industrial processes.—Taylor Instrument Companies, Rochester, N. Y.

U-324 **Industrial Instruments.** 12-page Bulletin W 1811 lists stock instruments—recorders, controllers, etc.—for immediate delivery.—The Bristol Co., Waterbury 20, Conn.

Valves

U-325 **High-pressure Solenoid Valves.** 8-page illustrated brochure describes maker's high-pressure pilot-operated solenoid valves for pressures to 3000 psi. Includes features and typical applications.—Waterman Engineering Co., 725 Custer Ave., Evanston, Ill.

Electrical and Electronic Instruments

U-326 **Electronic Equipment Reliability".** 21-inch wall chart by Ralph R. Batcher, RTMA Chief Engineer, presents "The Fourteen Points for Designers.—Radio Television Manufacturers' Ass'n., 489 Fifth Ave., New York 17, N. Y.

U-327 **Power-level Recorder.** 8-page illustrated brochure describes new recorder with square-law detector that records power level in db. for field-pattern measurement, etc. Includes principle, design, and specifications.—Leeds and Northrup Co., 4907 Stenton Ave., Phila. 44, Penna.

U-328 **Strain Measurement.** 12-page Vol. 2 No. 1 issue of "Hathaway Engineering News" features articles on strain measurement and use of maker's high-speed recording oscillograms.—Hathaway Instrument Co., 1315 S. Clarkson, Denver, Colo.

U-329 **Oscilloscopes, Amplifiers, Generators.** 60-page illustrated catalog covers maker's line of cathode-ray oscilloscopes, amplifiers, square-wave generators, and accessories. Includes descriptions and specifications.—Tektronix, Inc., P. O. Box 831, Portland 7, Ore.

U-330 **Electrometer.** 4-page binder and 2 filler sheets describes new "Model 200" vacuum-tube electrometer, "Model 2001" electrometer shunt and "Models 2002 and 2003" electrometer voltage dividers.—Keithley Instruments, 3868 Carnegie Ave., Cleveland 15, Ohio.

U-331 **Industrial Electronic Instruments.** 28-page Form 2J-8174 describes precision instruments, electron microscopes and electron diffraction equipment, vacuum systems, metal detectors, dielectric and induction heating equipment, inspection machinery, industrial TV, 16-mm. sound projectors, tubes, batteries, and test equipment.—Indus-

trial Equipment Sec., Engineering Products Dep't, Radio Corporation of America, Camden 2, N. J.

U-332 **Test Instruments.** 6-page folder Catalog 52-A illustrates and describes maker's line of test instruments —VTVM, marker-generator, high-voltage probe, etc.—Precise Development Corp., Oceanside, N. Y.

U-333 **Using the VTVM.** 48-page book "Servicing Radio and Television with a Vacuum-tube Voltmeter" is an educational publication describing VTVM applications and recommended procedures.—Sylvania Electric Products Co., 1740 Broadway, New York 19, N. Y.

U-334 **Magnetic-properties Measurement.** 12-page Publication GEC-777 describes gaussmeter, indicating fluxmeter, recording fluxmeter, and fluxmeter calibrating unit.—General Electric Co., Schenectady 5, N. Y.

U-335 **Industrial Electrical Instruments.** 64-page illustrated Catalog 48 lists maker's large line of test instruments, switchboard instruments, pyrometers, service instruments, etc., handled by large distributor.—Electro-Tech Equipment Co., 117 Lafayette St., New York 13, N. Y.

U-336 **Metal Detector.** 2-page illustrated bulletin describes maker's "Detectron Model 27" which weighs only nine pounds and detects buried metal. Includes sensitivities to various objects. —The Detectron Co., 5631 Cahuenga Blvd., N. Hollywood, Calif.

U-337 **Displacement Transducers.** 2-page Catalog pages 211-1 and 211-2 illustrate and describe maker's new "Series 211" displacement pickups that use precision potentiometers actuated by rectilinear motion. Includes features and specifications.—Colvin Laboratories, Morristown, N. J.

U-338 **Potentiometers.** 12-page illustrated Bulletin 270 covers maker's line of high-precision, microvolt, deflection, portable, and temperature-calibrated potentiometers.—Rubicon Co., Ridge Ave. at 35th St., Phila. 32, Penna.

U-339 **Semi-precision Potentiometers.** 4-page No. 1 issue of "Rubicon Notes" discusses features and principles of maker's single-and two-dial semi-precision potentiometers.—Rubicon Co., Ridge Ave. at 35th St., Phila. 32, Penna.

U-340 **Crystal Oscillator.** 8-page Vol. 26 No. 9 issue of "The General Radio Experimenter" describes new unit crystal oscillator that provides harmonics of 1 Mc., 100 kc., and 10 kc. to 1000 Mc. Also described is maker's 1-Mc. "Type 716" Schering bridge.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-341 **Decade Oscillators.** 2-page illustrated brochure contains features of maker's "Decalator Model 10-100" oscillator with 9000 separate outputs in 10-cycle steps from 10 to 100 kc.—Decade Instrument Co., Box 135, Caldwell, N. J.

U-342 **Data Converter.** 4-page illustrated brochure describes new cathode-ray-tube "Charactron" that displays messages on face of tube. Includes uses as analog and digital data converter and

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Calibration: within 1½% plus 1/10 cycle
Output circuits: 20 volts or 20 milliamps and 1 volt at 300 ohms constant impedance
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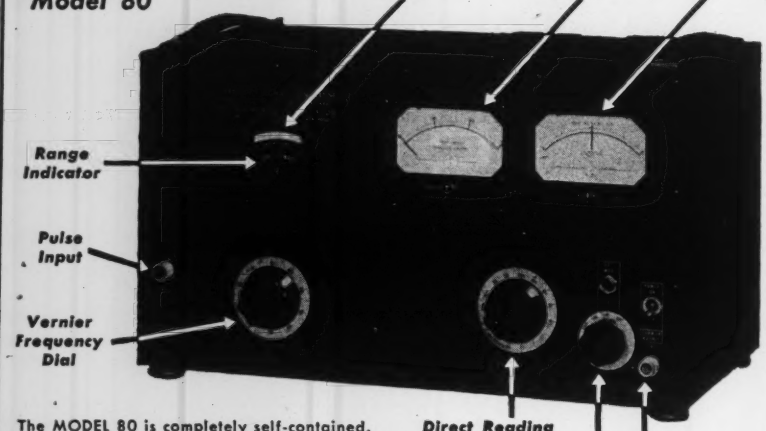

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NEW LITERATURE

as high-speed printer.—Consolidated Vultee Aircraft Corp., San Diego, Calif.

U-343 **Preamplifier.** 4-page brochure illustrates and describes new "Model A-800" audio preamplifier. Includes features and circuit.—Approved Electronic Instrument Corp., 142 Liberty St., New York 6, N. Y.

U-344 **Power Supplies.** 4-page brochure illustrates and gives specifications of maker's line of 16 regulated d-c. power supplies.—Kepco Laboratories, Inc., 131 Sanford Ave., Flushing 55, N. Y.

U-345 **Indicating Instruments.** 2-page brochure illustrates and describes maker's microammeters, voltmeters, and other unsealed and hermetically sealed meters.—Mil Instrument Corp., 37-01 Vernon Blvd., Long Island City 1, N. Y.

U-346 **Test Instruments.** 4-page brochure illustrates and describes maker's test instruments—intensity meter, UHF impulse generator, UHF attenuator, crystal mixer, and distortion analyzer. —Empire Devices, Inc., 38-25 Bell Blvd., Bayside 61, N. Y.

U-347 **Magnetic Amplifiers.** 4-page bulletin describes and gives characteristics of a new line of packaged push-pull standard magnetic-amplifier units. —Magnetic Amplifiers, Inc., 11-54 44th Drive, Long Island City 1, N. Y.

U-348 **Flight Instruments.** 20-page Winter 1952 issue of "Collins Signal" features 6-page article "Flying the Picture" on a new flight system which gives pilot a graphic display of his plane's position.—Collins Radio Co., Cedar Rapids, Iowa.

U-349 **Oscilloscope Voltage Calibration.** 16-page Jan. 1952 issue of "The CD Capacitor" features a 6-page article on how to assemble and use an instrument for calibrating CRO voltage.—Cornell-Dubilier Electric Corp., Hamilton Blvd., Plainfield, N. J.

U-350 **Test Instrument Kits.** 16-page "1952 Heathkit Catalog" lists numerous subassemblies and components whereby amateurs and professionals can build various types of test equipment.—Heath Co., Benton Harbor, Mich.

U-351 **Generator of Electrical Noise.** 12-page Vol. 26 No. 7 issue of "General Radio Experimenter" features 8-page article on a new controllable source of random electrical noise which makes possible new testing methods.—General Radio Co., 275 Massachusetts Ave., Cambridge 39, Mass.

U-352 **Attenuators.** 16-page Catalog 18-A describes and gives detailed technical data on numerous types of variable attenuators with wire-wound resistors.—Cinema Engineering Co., 1510 W. Verdugo Ave., Burbank, Calif.

U-353 **Electrical Ground Testers.** 2-page data sheet presents information on seven models of "Vibroground" instruments for every ground-resistance testing purpose.—Associated Research, Inc., 3758 W. Belmont Ave., Chicago 18, Ill.

U-354 **Sound Projector and Recorder.** 9-sheet mimeographed announcement with Q & A section and attached photographs describes new "Soundstrip" system of magnetic coating on motion-picture film.—Bell & Howell Co., 7100 McCormick Rd., Chicago 45, Ill.

U-355 **Electric Indicating Panel.** 1-page bulletin describes a panel assembly of four electric indicating instruments: voltmeter, ammeter, wattmeter and varmeter acting as an integrated unit.—System Analyzer Corp., 1327 N. Market St., Milwaukee 2, Wis.

U-356 **Carrier Telephone Systems.** 4-page illustrated Form 33C-P4 describes broad-band single-sideband multi-channel communication system. Includes block diagrams and technical summary.—Lenkurt Electric Co., Inc., 1105 County Rd., San Carlos, Calif.

Motors

U-357 **Motor Tester.** 4-page illustrated brochure describes new "PMD" motor tester which uses induction principle to test stators, rotors, field windings, and armatures. Includes principles and applications.—Columbia Technical Corp., 5 E. 57th St., New York 22, N. Y.

U-358 **Fractional-hp. Motors.** 32-page catalog contains illustrated bulletins covering maker's large line of fractional-hp. electric motors. Includes features and specifications.—John Oster Mfg. Co., Racine, Wis.

U-359 **Permanent-magnet Motors.** 1-page brochure illustrates and describes maker's line of small permanent-magnet d-c. motors.—Lindsay Products, Inc., 5645 Selmaraine Dr., Culver City, Calif.

Electrical and Electronic Components

U-360 **Electronic Components and Equipment.** Radio's Master, 16th Ed., 1952 Catalog contains over 1000 pages describing large line of many thousands of electronic components and equipment handled by large distributor.—Milo Radio & Electronics Corp., 200 Greenwich St., New York 7, N. Y.

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U-361 **Electronic Components and Instruments.** 164-page Catalog 1952 illustrates and describes thousands of electronic components, instruments, and supplies handled by large distributor.—Sun Radio & Electronics Co., Inc., 122 Duane St., New York 7, N. Y.

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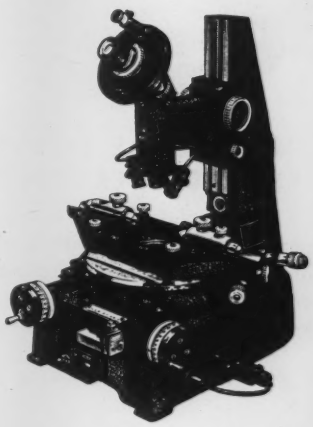

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NEW LITERATURE

ment No. 129 lists hundreds of items, including electrical instruments handled by large distributor.—Allied Radio Corp., 833 W. Jackson Blvd., Chicago 7, Ill.

U-363 **Resistors.** 8-page Bulletin PC2 and 2-page Bulletin PW1 give technical details on "Carb-Ohm" and "Wire-Ohm" resistors, now available in a wide range of values.—Phaostron Co., 151 Pasadena Ave., So. Pasadena, Calif.

U-364 **Negative-coefficient Resistors.** 8-page Bulletin 13 describes properties, performance, and application factors on maker's negative-temperature-coefficient resistance units.—Keystone Carbon Co., St. Marys, Penna.

U-365 **Trimmer Capacitors.** 2-page Bulletin 604 describes "Type A08" ceramic trimmers for applications where maximal stability is required.—Herlec Corp., 422 N. 5th St., Milwaukee 3, Wis.

U-366 **Transformers and Reactors.** 1-page bulletin lists and gives characteristics of new line of hermetically-sealed miniature transformers and reactors.—Southwestern Industrial Electronics Co., 2831 Post Oak Rd., Houston, Texas.

U-367 **Constant-voltage Transformers.** 22-page Booklet CV-142 is up-to-date cross reference to maker's large line of constant-voltage transformers, including latest new additions, descriptions, specifications, etc.—Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill.

U-368 **Controlled Inductance.** 4-page illustrated brochure describes new "Increductor" that utilizes separate control and signal windings arranged on a ceramic core. Inductance of signal winding can be varied over wide range by a-c. or d-c. variations in control winding, thus making possible applications as magnetic amplifier, frequency-controller, etc. Includes circuits and applications.—C. G. S. Laboratories, Inc., 391 Ludlow St., Stamford, Conn.

U-369 **Low-mu Twin Power Triode.** 2-page bulletin gives technical data on new RCA-6082 tube.—Tube Dep't, Radio Corp. of America, Harrison, N. J.

U-370 **Connectors.** 12-page Bulletin LS5-1951 describes experimental switchboard and laboratory cord connectors, including two new fittings.—Cannon Electric Co., P. O. Box 75, Lincoln Heights Sta., Los Angeles 31, Calif.

U-371 **Connectors.** 24-page Bulletin GB4-1951 describes maker's battery connector series used primarily for connecting and disconnecting starting equipment.—Cannon Electric Co., P. O. Box 75, Lincoln Heights Sta., Los Angeles 31, Calif.

U-372 **Connectors.** 6-page folder contains introductory description of new line of r-f. connectors, plugs, terminal assemblies, etc.—Waltham Horological Corp., Waltham 54, Mass.

U-373 **Grounding Sheath Connectors.** 4-page illustrated Bulletin S5 describes maker's 2-piece compression-type con-

nectors for terminating braided shields on wire and cable. Includes installation and operation.—The Thomas & Betts Co., Elizabeth, N. J.

U-374 **Deflecting Yoke.** 2-page bulletin gives technical data on RCA-212-D1 magnetic deflection yoke for CR tube in flying-spot scanning equipment.—Tube Dep't, Radio Corp. of America, Harrison, N. J.

U-375 **Hermetically-sealed Relays.** 4-page illustrated brochure contains descriptions and specifications of maker's line of rugged, sealed relays.—Price Electric Corp., Frederick, Md.

U-376 **Remote-control Relays.** 2-page Form No. 866 (insert sheet for Catalog 17) describes mercury-plunger relays in weather-proof housings.—H B Instrument Co., 2633 Trenton Ave., Philadelphia 25, Pa.

U-377 **Time-delay Relay.** 4-page Bulletin 5001A illustrates and describes new "Silic-O-Netic" relay which employs a new electric time-delay mechanism unaffected by fatigue, dirt, dust, moisture, etc.—Heinemann Electric Co., Trenton 2, N. J.

U-378 **Test Prods.** Envelope-size folder describes eleven "Klipzon" test prod devices for laboratories and for radio-TV servicing. Also a reprint of a 3-page article on crystal-probe applications.—United Technical Labs, Morristown, N. J.

Mechanical Components

U-379 **Mechanical Springs.** 8-page Feb. 1952 issue of "The Mainspring" contains article on alloys versus straight carbon steel.—Associated Spring Corp., Bristol, Conn.

U-380 **Beryllium-copper Springs.** 2-page Jan. 1952 issue of "Berylco Technical Bulletin" is an article on the use of beryllium copper springs in "Agastat" time delay relays.—The Beryllium Corp., Reading, Penna.

U-381 **Plastics for Instruments.** 4-page Jan.-Feb. 1952 issue of "Amphenol Engineering News" describes instrument applications of "Amphenol" materials.—American Phenolic Corp., 1830 S. 54th Ave., Chicago 50, Ill.

U-382 **Plastics for Instruments.** 8-page Jan. 1952 issue of "Durez Plastic News" contains articles on use of special plastics in slide viewers, potentiometers, and switches.—Durez Plastics & Chemicals, Inc., North Tonawanda, N. Y.

U-383 **Speed Changers.** 2-page Technical Data Sheet 7 describes maker's "Series 7" anti-backlash miniature speed changers. Includes principles and applications.—Metron Instrument Co., 432 Lincoln St., Denver 9, Colo.

U-384 **Aircraft Fastener.** 4-page Feb. 1952 issue of "Airsoc News" features article on new "Vibrex" fastener which eliminates rattles and damps vibration.—Air Associates, Teterboro, N. J.

U-385 **Expanding Fasteners.** Two 1-page leaflets illustrate and describe new "Vibrex" fasteners for instrument panels, instrument cases, etc.—Air Associates, Teterboro, N. J.

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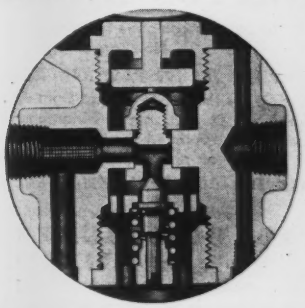

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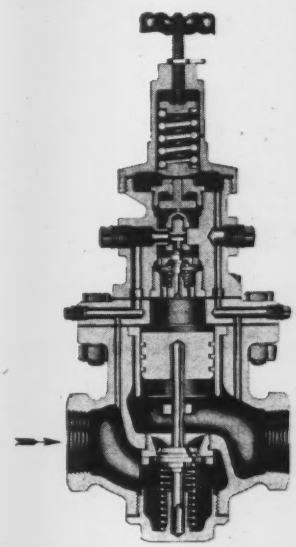

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